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THE ROLE OF METACOGNITIVE MONITORING AND CONTROL IN OVERCOMING COGNITIVE OVERLOAD DURING THE IMPASSE PHASE

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ABSTRACT

This study was motivated by the urgency of the phenomenon of cognitive overload, which often triggers a phase of impasse or mental block in students when solving contextual mathematics problems. This condition causes students to often rush to apply irrelevant calculation procedures without analyzing the structure of the problem, resulting in strategic failure. This study aims to describe in depth the dynamics of students' metacognition, particularly the monitoring and control functions, and to analyze the effectiveness of visualization strategies in reducing this cognitive load. The research method used is a qualitative approach with a descriptive-exploratory design. The research subjects included junior high school students who were tested on their ability to solve PISA-type questions. Data collection was carried out using the Think Aloud Protocol (TAP) technique to record students' mental processes and verbalizations in real time when they encountered a deadlock. Data were collected through the Think Aloud Protocol and analyzed using qualitative thematic procedures with interview triangulation. The results showed that the monitoring of metacognitive function plays a vital role as an early detection mechanism that helps students recognize anomalies between their tentative answers and the logic of the problem. Furthermore, the control strategy through image visualization proved effective in reducing extraneous cognitive load, enabling students to transform abstract representations into concrete ones and find the turning point for solving the problem. In addition to improving cognitive accuracy, successfully overcoming this impasse phase simultaneously increases students' self-efficacy or self-confidence. These findings recommend the importance of integrating metacognitive interventions in learning to build students' mathematical resilience.

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1. INTRODUCTION

Selecting the appropriate problem-solving strategy is the main foundation for students to achieve accurate and efficient mathematical solutions (William & Maat, 2020). However, the reality in the field shows that many junior high school students often rush to apply calculation procedures without analyzing the structure of the problem first. Based on the findings of Umam et al. (2025) Most student errors stem from a failure to evaluate the prerequisites of the problem, leading them to directly apply irrelevant arithmetic operations. This phenomenon causes students to become stuck in lengthy, conceptually flawed procedural steps. As a result, students' cognitive energy is drained just to perform computations that are actually unnecessary to answer the core question (Parwati & Suharta, 2020). Furthermore, this habit hinders students' ability to develop flexible thinking when faced with non-routine problems. Therefore, the issue of incorrect initial strategy selection is a pressing matter that must be thoroughly investigated to prevent the accumulation of misconceptions.

The problem of choosing a strategy becomes even more complex when students are faced with contextual problems or story problems that require mathematical literacy (Szabo et al., 2020). Students often have difficulty translating narrative sentences into representative mathematical models because of the gap between everyday language and formal symbols. A study by Tanudjaya & Doorman (2020) reveals that misunderstanding story problems contributes significantly to students' failure in mathematics tests. This inability often triggers mathematical anxiety, causing students to lose focus on the core of the problem at hand. Additionally, unfamiliar problem contexts often cause students to force memorized formulas that do not align with the logic of the problem situation (Vadivu et al., 2025). This condition is exacerbated when the numbers presented in the problem are in the form of fractions or decimals, which increases the level of perceptual difficulty. As a result, students often stop halfway or produce illogical answers.

The failure of strategies in contextual problems directly triggers a psychological condition known as the impasse phase or thinking deadlock (Guo & Liao, 2025). This phase occurs when students' working memory experiences overload or cognitive overload because they have to process textual and procedural information simultaneously. According to a systematic review on Chen et al. (2018) Poorly managed instructions will overload students' information processing capacity. When this cognitive load exceeds its limits, students will experience confusion, stagnation, and a loss of direction in problem-solving. This situation is characterized by repetitive behavior without progress, such as scribbling on paper or recalculating the same numbers. Cognitive overload not only hinders cognitive processes but also reduces students' motivation to continue working on problems (Jatmiko et al., 2025). Thus, understanding the dynamics of this impasse phase is crucial for designing appropriate interventions for students who experience learning difficulties.

In such a stressful impasse situation, the role of metacognition, particularly in terms of monitoring, becomes vital in saving students' thinking processes (Khasawneh et al., 2021). Monitoring metacognition is defined as students' active awareness in observing and evaluating the status of their understanding and progress in solving their own problems in real time (William & Maat, 2020). Research by Sawah & Kusaka (2025) confirms that students with good monitoring skills can detect strategy errors faster than other students. This ability allows students to realize the discrepancy between their preliminary calculations and the actual logic of the problem. The error signals generated by this monitoring process serve as a warning alarm for students to stop the strategy they are currently using. Without effective monitoring, students will continue to be trapped in the same error without realizing that they are heading toward a dead end (Scheibe et al., 2023). Therefore, this error detection mechanism is the first step that determines the success of students' self-regulation.

After an error is detected through monitoring, the next step that students must take is to activate the control metacognition strategy (Rifai et al., 2026). Control metacognition is defined as the ability of students to make executive decisions to modify, change, or adjust thinking strategies in response to previous failures (Güner & Erbay, 2021). These strategies include rereading questions, simplifying problems, or switching representations from symbolic to visual to unravel complexity. Studies conducted by Tachie (2019) show that students who are capable of cognitive control tend to be more resilient when faced with PISA or HOTS-type questions. This change in strategy is evidence of students' mental adaptability in finding alternative paths when the main path is blocked. By exercising appropriate control, the previously high cognitive load can be reduced to a level that is more manageable by working memory. Ultimately, it is this control strategy that transforms a situation of deadlock into a new opportunity to find the correct solution.

Various previous studies over the past five years have extensively examined the relationship between metacognition and mathematics learning outcomes in general (Bakar & Ismail, 2020; Hidayati et al., 2025; Jatmiko et al., 2025; Masduki et al., 2020; Sawah & Kusaka, 2025; Scheibe et al., 2023; Vadivu et al., 2025). The majority of these studies used a quantitative approach in the form of large-scale surveys to measure the correlation between metacognitive awareness and students' academic achievement. The findings consistently show that there is a significant positive relationship between metacognitive ability and mathematical problem-solving ability. In addition, several experimental studies have also proven that training in metacognitive strategies can effectively improve students' math test scores (de Bruin et al., 2017; Niyazova et al., 2022; Tupamahu et al., 2023). However, these studies generally only look at the final results of students' thinking processes without recording the dynamics of the changes. As a result, the internal mechanisms that occur second by second when students switch strategies are still not fully understood.

In line with this, most existing qualitative studies still focus on describing students' errors without exploring the recovery process (Diarni et al., 2023; Nuryadi et al., 2024; Putri Hapsari et al., 2022). Many studies have successfully identified the types of student errors in fraction material, but few have examined how students correct these errors independently (Barbosa & Vale, 2021; Rosikhoh, 2024; Starling-Alves et al., 2021). Previous research has focused more on diagnosing student weaknesses than on analyzing the potential of their self-regulation strengths when under pressure. In fact, the moment when students recover from failure is rich in information about the actual learning process. The existing literature has not specifically discussed the role of image visualization as a control strategy to reduce cognitive overload. Therefore, there is still a gap in the literature that needs to be filled regarding the micro-genetic profile of students' metacognition in critical situations.

Based on this research gap, there is an urgent need to conduct in-depth investigations using the Think Aloud Protocol method to capture students' mental processes in real time. A study is needed that specifically highlights the moment of transition from the impasse phase to the discovery of solutions through independent metacognitive intervention. This study offers novelty by placing changes in visual representation as the main unblocking mechanism driven by students' control functions. This approach is expected to reveal students' thinking problems that have not been accessible to conventional written tests. In addition, this study will also link this cognitive success with its affective impact on students' self-confidence. Thus, this study is expected to provide original theoretical contributions regarding the dynamics of mathematical problem solving. This novelty is very important for formulating learning strategies that are more responsive to students' difficulties.

Based on the background of the problem described above, the research question in this study focuses on how students' metacognitive dynamics work when faced with a dead end. This study aims to describe in detail the metacognitive profile of students in detecting errors (monitoring) when they are in a confusing impasse phase. Furthermore, this study also aims to analyze the effectiveness of control strategies, particularly the use of image visualization, in reducing the cognitive overload experienced by students. In addition to cognitive aspects, this study aims to explain how the change in strategy from counting to images becomes a turning point for successful problem solving. Furthermore, this study will reveal scientific contributions regarding the impact of this process on the final affective aspect of students in the form of increased self-efficacy. Through the achievement of these objectives, it is hoped that a micro-theoretical model explaining students' cognitive resilience can be developed. The answers to these questions will provide new insights for educators in guiding students who experience difficulties in learning mathematics.

2. METHOD

This study applies a qualitative approach with a descriptive-exploratory design to investigate in depth the dynamics of students' metacognition when faced with complex problem-solving situations. This approach was chosen based on the study's objective to uncover issues in students' thinking processes that cannot be addressed through conventional written tests alone, as well as to capture real-time micro-genetic profiles of metacognition. In line with the urgency to understand the internal mechanisms when students switch strategies, this design allows researchers to record, second by second, students' mental transitions from the impasse phase to the discovery of solutions through independent metacognitive intervention. The main focus of this method is to describe how the monitoring function detects errors and the control function modifies strategies to reduce cognitive overload.

The subject in this study was one junior high school student selected using *purposive sampling*. The criteria for subject selection included: (1) having studied fractions, (2) having good verbal communication skills to support the *Think Aloud* method, and (3) experiencing a phase of *impasse* (deadlock) detected during the initial instrument trial. The selection of a single subject aimed to obtain an in-depth and detailed microgenetic profile of *real-time* cognitive processes.

The main data collection technique in this study used the Think Aloud Protocol (TAP) method, in which subjects were asked to voice everything they thought while working on math problems. The instrument used was a PISA-type contextual problem specifically designed with a certain level of complexity, involving fractions and narratives that required mathematical literacy, to trigger cognitive load on students' working memory. The use of story problems about rice consumption aimed to create a situation in which students were likely to experience initial strategy errors, allowing researchers to directly observe how students responded to these deadlocks through changes in visual representation. The following are the problem instruments used to stimulate this cognitive process. The TAP was conducted following Ericson & Simon's standard procedure, modified into three stages:

1. ***Warm-up* Stage:** Subjects were given simple practice questions to familiarise themselves with voicing their thoughts without feeling judged.
2. **Core Work Stage:** Subjects were asked to solve the rice consumption problem while spontaneously saying whatever came to mind. The researcher did not provide content

assistance, only verbal encouragement such as 'keep talking' if the subject was silent for more than 5 seconds.

3. **Recording and Observation:** All verbal activities were recorded using a voice recorder, while non-verbal activities (scribbling, drawing) were recorded through direct observation and documentation of the students' worksheets.

Metacognitive activities were identified through the following operational indicators:

1. ***Monitoring***: Identified through verbal indicators such as expressions of doubt (e.g., "Eh, that's strange, isn't it?") or acknowledgement of errors when checking results (e.g., "Oh yes, there's still some left"). Visually, *monitoring* was evident when students paused to compare the image with the question narrative.

2. ***Control***: Identified through noticeable changes in strategy, such as switching from trying symbolic division formulas to creating visual representations (drawing boxes). *Debugging* or combining remaining fraction units into a new whole is also categorised as a *control* function.

Figure 1. Question to determine Cognitive Overload during the Impasse Phase

The problem instrument was validated through *expert judgement* by two mathematics education experts to ensure content appropriateness and readability. Although mathematically this problem can be solved with one division step (25 ÷ 0.75), the use of pure fractions (3/4) was deliberately chosen to trigger *intrinsic cognitive load* in secondary school students who still rely on routine procedures. The image of a sack of rice on the instrument (Figure 1) served as a contextual stimulus, while the image of a box created independently by the subject (Figure 3) was a form of *external memory* that was crucial for reducing *working memory* load.

After the verbal data were collected, data analysis techniques were systematically applied to translate the audio recordings and field notes into complete data transcripts. This process began with transcribing all of the students' verbalizations and sorting the data based on segments of behavior that indicated metacognitive activity, whether it was monitoring when they realized a mistake or control when they decided to draw a visualization. This verbal data is then analyzed to see the consistency between what students say and the writing or drawings they produce, to ensure the validity of inferences about their level of understanding. This analysis not only focuses on diagnosing errors but also explores the potential for students' self-regulation when they recover from failed strategies.

The next stage of data analysis follows a structured workflow, starting from data reduction and presentation, and concluding. Based on the analysis framework, the abstracted data is then categorized or coded to construct a schema of students' thinking structures, which includes identifying turning points or points of success in problem solving. This scheme will map the relationship between the reduction in cognitive load and the increase in students' self-efficacy after successfully overcoming challenges. The entire series of qualitative data analysis processes based on the Think Aloud Protocol applied in this study is described in the following flowchart.

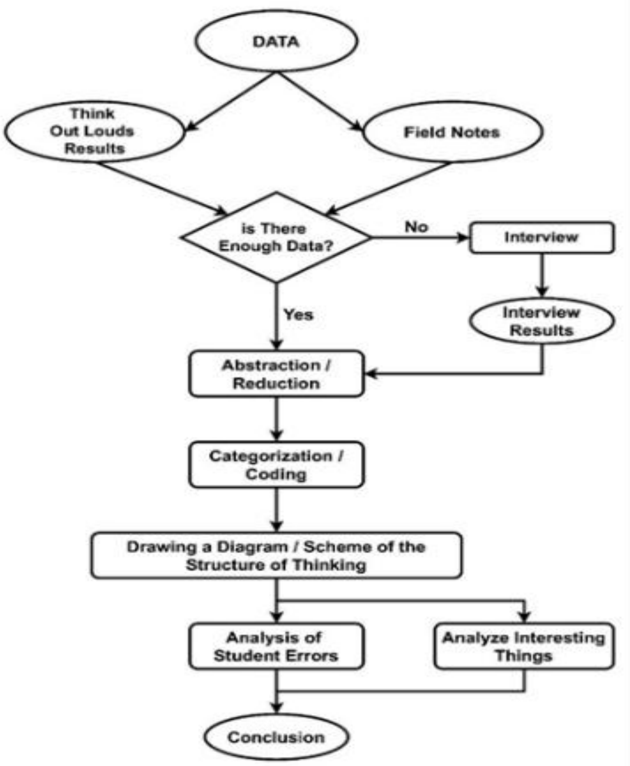

Figure 2. Data Analysis Process Using Qualitative Method Based on Think Aloud Protocol

3. RESULTS AND DISCUSSION

3.1. Results

This section describes empirical findings regarding the dynamics of students' metacognition in overcoming the impasse phase caused by cognitive overload when solving contextual mathematical problems. Through the Think Aloud Protocol (TAP) analysis technique, students' initially abstract thinking processes were successfully externalized, enabling researchers to track in real time the mental transition from procedural confusion to the discovery of visual solutions. The following data presentation is arranged chronologically to visualize the students' complete micro-genetic profiles, beginning with the verbal tracking of monitoring and control activities in Table 1, concrete evidence of changes in representation strategies in Figure 3, and validation of affective and cognitive impacts through in-depth interviews in Table 2. The integration of these three data sources aims to prove how independent metacognition intervention acts as the main unblocking mechanism in solving the complexity of fraction problems.

To answer the research objective regarding the micro-genetic profile of students when solving problems, table 1 below outlines the transcripts of students' verbalizations recorded using the Think Aloud Protocol method. These data reveal problems found in students' cognition, showing the moment-by-moment transition from declarative knowledge to active metacognitive regulation when counting strategies are no longer adequate.

Table 1. Think Aloud Protocol Results

Student Steps in the Rice Problem	Metacognitive Awareness Category	Indicators	Detailed Explanation
Describing 1 kg as 1 box and making 25 boxes	Metacognitive Knowledge & Regulation	Planning	Demonstrate declarative knowledge (understanding of unit concepts), procedural knowledge (drawing representations), and strategic planning to understand problems.
Divide each box into 4 parts (0.25 kg)	Metacognitive Knowledge	Procedural & Conditional	Demonstrating the ability to choose fraction representation strategies and understanding why visual division is necessary for accuracy.
Shading 3 parts per box (0.75 kg per day)	Metacognitive Regulation	Monitoring	Students monitor whether the shading corresponds to daily usage by ensuring that the steps are consistent with the information in the question.
Conclude early on that the rice will run out in 25 days	Metacognitive Knowledge	Declarative	Based on the initial understanding of the representation, it is not yet completely accurate.
Rechecking the results and finding a remaining 0.25 kg/day	Metacognitive Regulation	Advanced monitoring	Students realize that there is a discrepancy between the visual model and the final results.
Combining the remaining 0.25 kg over 3 days into 1 additional day	Metacognitive Regulation	Evaluation & Debugging	Students refine their strategies, evaluate the effectiveness of their initial approach, and choose a more appropriate solution.
Concluding: Rice runs out in 33 days	Metacognitive Regulation	Evaluation	Demonstrates full control over the thinking process and the ability to revise answers based on self-evaluation.

Based on table 1, it is clear that students' metacognitive activities are not static, but dynamic in line with the level of difficulty encountered. In the initial stage, the Metacognitive Knowledge indicator dominates when students plan their representation of the problem by drawing 25 boxes.

As empirical evidence of metacognitive activity recorded in TAP, Figure 3 below presents visual traces of students' work illustrating a shift in strategy from symbolic-abstract to iconic-concrete representation.

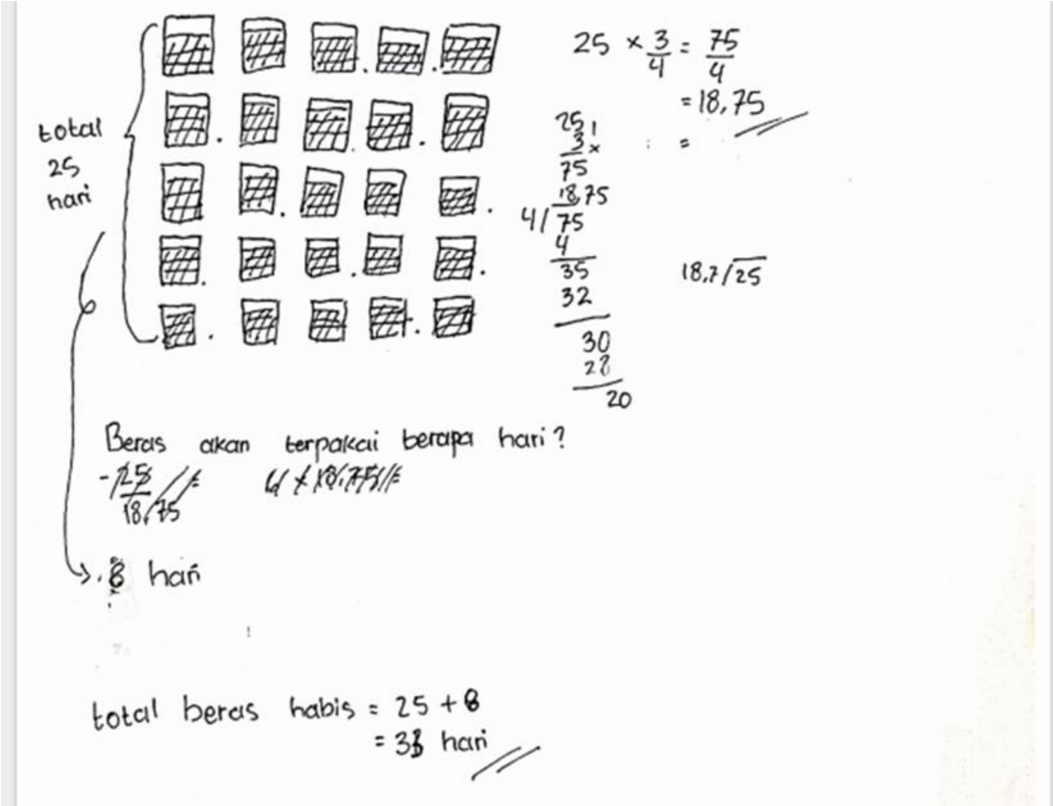

Figure 3. Student Work Results

Figure 3 shows how students organize complex information into more manageable visual units. The row of 25 boxes divided into four smaller sections is an external memory technique that allows students to deepen their understanding of the information without overloading their brain capacity.

To validate the researchers' inferences regarding these cognitive processes and explore the affective impact after problem solving, in-depth interviews were conducted, the results of which are summarized in Table 2. These transcripts serve as data triangulation to ensure that the changes in strategy made by students were truly based on metacognitive awareness and not merely a coincidence.

Table 2. Student Interview Results

Variable / Metacognitive Stage	Researcher's Questions	Student Responses	Researcher Analysis
Impasse & Cognitive Overload Phase (Detecting initial deadlock)	When you first read the story about the 25 kg of rice, how did you feel? Did you immediately know how to calculate it, or were you confused?	To be honest, I was confused, ma'am. The numbers were fractions (3/4), and the story was long. I wanted to divide 25 by 3, but it didn't feel right. So, I paused for a moment, afraid of making a mistake if I used the formula.	Students experience cognitive overload because they have difficulty translating the narrative of the problem into mathematical symbols directly.

Metacognitive Control (Drawing Strategy)	Look, here the student drew many boxes, up to 25. Why did they choose to draw instead of just calculating the numbers?	Because just thinking about it makes me dizzy, Ma'am. So, I just drew one sack as one box. There are 25 kg, so I made 25 boxes to clarify the rice rations.	Active Control Strategy: Students convert abstract mental representations into concrete visuals to reduce cognitive load.
Conceptual Understanding (Representation)	Then, in each box, some are shaded, and some are white. Can you explain what this drawing means?	Well, Mom cooks 3/4 of a kilogram per day. So, I divide one box (1 kg) into 4 pieces. I shade 3 pieces in black, which means the rice ration for one day of cooking.	Students demonstrate procedural understanding by breaking down units into appropriate visual fractions.
Monitoring Metacognition (Error Detection)	In the audio recording, you said 25 days, but then you corrected yourself. What did you see in the picture that made you realize that the answer of 25 days was not correct?	Yes, at first, I thought it was 25 days because there were 25 boxes. But when I checked the picture again (monitoring), I realized that there was still a small white piece left in each box that was not shaded. It would be a shame to throw it away, because it could still be used for cooking.	Monitoring function is active: Students detect the incompleteness of the initial solution by looking for residues or remnants in the visual model.
Metacognition Control & Debugging (Strategy Improvement)	Well, that's right, there are leftovers. Then, how did you find the additional number 8 days below here? Even though the leftovers are only small amounts?	I collected the leftovers, Ma'am. One day requires 3 small pieces (3/4). So, I took the leftovers from 3 boxes and combined them into one more day's worth of food. I counted all the leftover pieces, and it turned out to be enough to add 8 more days.	Debugging Strategy: The student performed visual manipulation (combining partial leftovers) to find the complete solution.
Final Results & Self-Efficacy (Self-Confidence)	So, the total is 33 days. After successfully finding the answer using pictures, how do you feel now compared to when you started?	I feel so relieved, Ma'am. It turns out that when you draw it, it becomes easier to see, not as complicated as I thought when I first read the question. I'm now more confident that the answer is 33 days.	There was an increase in Self-Efficacy and a decrease in anxiety after successfully overcoming the impasse phase.

The interview results in table 2 explicitly confirm the occurrence of cognitive overload at the beginning of the task, where students admitted to feeling confused and afraid of making mistakes when faced with the narrative questions.

3.2. Discussion

The Phenomenon of Cognitive Overload as a Trigger for the Impasse Phase in Problem Solving

The rice consumption problem presented in this study was found to trigger high cognitive load in students, mainly due to the integration of complex contextual narratives with abstract fractional concepts (3/4 kg). These findings show that the intrinsic cognitive load inherent in the difficulty level of the material was the main obstacle preventing students from directly accessing the standard division algorithm. When students read the question, their working memory must not only process numbers, but also translate the unusual rice remainder scenario into routine arithmetic operations (Prasetiyo & Walida, 2025). This condition creates a bottleneck or information blockage, causing students to experience a momentary blank or deadlock, known in cognitive psychology literature as the impasse phase.

The impasse phase experienced by students is not merely a sign of ignorance, but rather a cognitive state in which the automatic strategies normally used are no longer effective. In this context, students' verbal data showing doubt and confusion is consistent with research conducted by Larmuseau et al. (2020). Referring to a systematic review conducted by Utaminingsih et al. (2024) It is mentioned that instructions or problems with high element interactivity will paralyze beginners if they do not have adequate mental schemas. In this case, the interaction between a total of 25 kg and a consumption of 3/4 kg creates a complexity that exceeds the processing capacity of students. The black shading on three sections of the boxes (representing 0.75 kg) provides visual clarity that makes it easier for students to see the remaining pattern (the white sections). At the bottom left of the image, the additional 8-day calculation scribbles are physical evidence of the turning point or success point for students. This confirms that the use of visualization strategies is very effective in reducing the perceptual complexity of fraction problems, allowing students to overcome the impasse that previously hindered their thinking process.

An interesting finding that contradicts common assumptions is that impasse is actually an important prerequisite for active metacognition. Previous studies often considered deadlock to be a final failure, but the Think Aloud analysis in this study shows the opposite. The impasse forces students to pause and evaluate the situation, a process that rarely occurs in routine problems where students tend to work automatically without thinking deeply. This is supported by the study Putri et al. (2024), which found that students with high metacognitive abilities often use moments of confusion as a signal to switch strategies, rather than as a sign to give up.

However, not all students can manage this cognitive load well without the intervention of appropriate strategies. Referring to the research by Dahiana et al. (2023) on the impact of representation on cognitive load, students who continue to use purely verbal or symbolic representations when experiencing overload tend to experience failure and frustration. In this study, the students who successfully emerged from the impasse were those who realized that their working memory could not hold all the fraction calculation information in their heads, so they needed external aids. This awareness distinguishes regulatory students from impulsive students.

Thus, it can be concluded that cognitive overload in contextual fraction problems serves as a double-edged sword. On the one hand, it has the potential to halt the thinking process of students who are not ready. However, on the other hand, for students with metacognitive potential, this excessive load actually becomes an effective trigger to activate higher-level awareness. This finding provides a new perspective that difficulties designed with the right measure in PISA questions are actually necessary to train students' mental muscles in dealing with unexpected situations (Prasetiyo et al., 2026).

The Vital Role of Metacognitive Monitoring in Answer Anomaly Detection

The aspect of metacognitive monitoring in this study was identified as the front-line defense that prevented students from making fatal mistakes. The monitoring process was very clear when students double-checked their answers after 25 days and found small pieces remaining in the picture. This activity is not merely looking at the image, but rather an active process of comparing students' mental models with the external representations they have created. Without a real-time monitoring function, students might be satisfied with the 25-day answer obtained from counting the number of large boxes, without paying attention to the remaining fragments. However, a crucial point arises in the advanced Monitoring stage, where students detect an anomaly in the form of a remaining fraction (0.25 kg) that breaks their initial conclusion (25 days). This finding confirms that the monitoring function acts as an effective early warning alarm that prevents students from getting stuck in conceptual errors. Furthermore, the step of combining the remainder at the end of the table shows the functioning of Metacognitive Control (evaluation & debugging), where students' metacognitive processes consciously modify strategies to accommodate overlooked variables, resulting in a precise solution.

The importance of monitoring in detecting these errors is reinforced by recent literature. A study from Hadi Sopandi et al. (2024) emphasizes that the main difference between expert and novice problem solvers is not in their knowledge of formulas, but in the frequency and accuracy of monitoring during the work process. Students in this study demonstrated expert characteristics on a micro scale, where they did not immediately trust their initial intuition. They performed what is known as reality checking by asking themselves questions, which then led them to revise their answers (Scheja & Rott, 2024).

These findings refute the assumption that junior high school students tend to be careless and inaccurate. On the contrary, the data show that when given the right visual aids, students are capable of highly precise self-correction. This is in line with the findings of Andrian et al. (2025), which states that students are capable of complex cognitive regulation if they are allowed to visualize their thoughts. Images or visualizations act as mirrors that reflect students' logical errors, making these errors visible and concrete, unlike abstract calculations, where errors are often hidden.

Furthermore, an in-depth analysis of the interview transcripts revealed that student monitoring was driven by a sense of inadequacy or intuitive uncertainty. These feelings are not weaknesses, but rather valuable metacognitive signals. In a study conducted Tomasetto et al. (2021) concluded that epistemic emotions, such as doubt, are recognized as an important component of monitoring. Students' doubts when seeing the remaining shading prompted them to reexamine their initial assumption that one box equals one day. This is where students' adaptive intelligence lies; they use these doubts as fuel to conduct further investigation, not to stop.

In conclusion, the monitoring function works as a highly effective early detection alarm. The students' success in detecting the remaining 0.25 kg proves that they are not only focused on the end result (product), but also on the validity of the process. This has theoretical implications that monitoring skills must be explicitly trained, as it is these skills that bridge the gap between near-correct answers and truly accurate answers. Without monitoring, even good visualization strategies can lead to incorrect conclusions.

Image Visualization as a Control Strategy for Cognitive Load Reduction

The students' decision to draw 25 boxes and divide them into smaller units is at the heart of the control metacognition strategy. This step is not merely an artistic act, but rather a sophisticated cognitive strategy for manipulating information. By transferring the calculation process from their heads to paper, students effectively reduce extraneous cognitive load (Paas & Van Merriënboer, 2020). This strategy allows students to rest their brains from the task of remembering fraction numbers, so that brain capacity can be redirected to a higher-level task, namely, analyzing the remaining rice patterns.

The study concluded that multimodal visual representations (images + narration) significantly improved students' conceptual understanding of geometry and fractions compared to single symbolic representations. In this case, box images provided a physical structure for abstract problems. Students can physically point, count, and cross out the remaining boxes. This motor and visual interaction creates embodied cognition, in which mathematical understanding is reinforced by the physical actions of drawing and shading.

These visualizations are not mere scribbles, but manifestations of the control strategies adopted by students to reduce cognitive overload on their working memory. This control strategy also demonstrates creativity in problem-solving. Students did not use the standard formula 25:(3/4) that may have been taught in class, but instead created ad-hoc algorithms or non-routine strategies that suited their own thinking logic. This phenomenon is in line with the research Ademmer & Prediger (2025) which found that students who are flexible in choosing strategies have a higher chance of success than students who are rigid in using one method. The ability of students to change strategies midway, from trying to calculate to drawing, is clear evidence of optimal brain executive function.

The process of combining remainders (taking 3 remainders of 0.25 to make an additional day) is the pinnacle of the success of the control strategy. This is a very elegant form of debugging or error correction. If students continue to use the division formula, they may get a decimal result of 33.333..., which is difficult to interpret in the context of days. However, with the image, the number 0.333... appears as a concrete remainder that can be intuitively combined. This proves that visualization not only simplifies the problem but also provides meaning (sense-making) that is often lost in calculator calculations (Adams & Barth-Cohen, 2024).

Thus, image visualization in this study serves as a Cognitive Offloading Tool (Medrano & Miller-Cotto, 2025). This control strategy validates the view that mathematical intelligence is not solely about mental calculation speed, but about the ability to use tools (including images) to aid the thinking process. This strategy successfully transforms complex and burdensome problems into visible and manageable ones, enabling students to overcome the limitations of their own working memory capacity.

Transformation of Self-Efficacy Through Mastery Experience

In addition to cognitive aspects, this study reveals the significant impact of metacognition on the affective domain, particularly students' self-efficacy or self-confidence. Based on interview data, there was a drastic shift from negative emotions (fear, confusion) at the beginning of the task to positive emotions (relief, confidence) at the end of the session. The students' success in finding the answer after 33 days of struggling to overcome the impasse provided them with a sense of mastery, which is the main source of self-efficacy. The students were not only happy that their answers were correct, but they also felt proud of having found the solution themselves (Rifai et al., 2026).

This increase in self-efficacy is relevant to recent findings from Alali & Wardat (2024), which states that self-efficacy and self-regulation are stronger predictors of problem-solving ability than simply reducing math anxiety. This means that building students' confidence that they can find a solution has a much greater impact than simply calming them down. In this study, the Think Aloud process and drawing provided students with physical evidence that they were capable of creating their own evidence, not just accepting what the teacher provided.

The study found that students trained in metacognitive strategies showed a significant increase in mathematical self-efficacy compared to the control group (Suherman & Vidákovich, 2025). This is because metacognition gives students control. When students know how to monitor and correct their mistakes (as the subjects in this study did), they no longer feel helpless when faced with difficult problems. They know they have the tools to fix them. The students' narrative that it turns out to be easy when drawn shows a change in perception of the difficulty level of the task (Rafiq-uz-Zaman et al., 2024). Problems that were initially considered impossible became possible to solve. This change in perception is crucial for building long-term resilience. Students learn that feeling stuck at the beginning is normal and can be overcome, not a sign of stupidity. This implicit lesson may be more valuable than the mathematical answer itself, as it fosters a never-give-up mentality.

This admission validates the research premise that uncertainty about strategy triggers high mental load. However, more important are the findings in the final segment of the interview, where students expressed feelings of relief and greater confidence. This statement is strong evidence that the success of the control strategy not only improves the accuracy of cognitive responses but also contributes significantly to increasing students' self-efficacy or self-confidence. Thus, independent metacognition intervention has been proven to be able to transform a stressful impasse into a learning experience that builds students' mathematical resilience.

In conclusion, the integration of cognitive success and metacognitive strategies has created a positive loop for student psychology. Success in overcoming cognitive overload not only results in good scores but also produces students who are more confident and resilient. This study confirms that the ultimate goal of mathematics learning should not only focus on the accuracy of answers, but also on shaping students' character so that they are confident in their own thinking abilities.

4. CONCLUSION

This study concludes that the dynamics of students' metacognition play a central role in transforming the impasse phase from a mere cognitive obstacle into a productive opportunity for problem solving. Specifically, the findings indicate that metacognitive monitoring functions as an early detection mechanism that prevents students from making fatal errors by identifying anomalies between temporary answers and visual logic. These findings answer the research objective by confirming that the failure of initial strategies due to cognitive overload can be overcome through the activation of control strategies, particularly image visualization, which functions as an external memory to reduce the burden of processing complex information. Thus, mental blocks are not a sign of permanent incompetence, but rather a crucial signal that triggers a transition from automatic thinking to more conscious and structured self-regulation.

Furthermore, analysis of the turning point shows that student success is not only determined by mastery of formulas, but also by mental flexibility in debugging or independently improving strategies. The decision to combine the remaining visual fragments into a new unit is empirical evidence that changing the representation from symbolic to iconic can bridge the gap in understanding that cannot be accommodated by procedural calculations alone. Cognitive success in overcoming these challenges simultaneously was associated with a positive shift in students’ self-efficacy that transforms mathematical anxiety into strong self-confidence. This confirms that metacognitive intervention has dual implications, namely improving the accuracy of mathematical solutions while building students' resilience.

The main contribution of this study to the world of education is the provision of a micro-theoretical model that educators can use to diagnose and guide students who experience learning difficulties, emphasizing the importance of space for visual exploration rather than just speed of calculation. It is hoped that these findings will encourage a shift in the teaching paradigm that values slow but deep-thinking processes, especially in subjects that require high literacy. For further research, it is recommended that the study be expanded to other domains of mathematics or involve subjects with more diverse cognitive styles in order to test the universality of this self-regulation model, so that more inclusive and adaptive intervention strategies can be formulated for the entire spectrum of student abilities.

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