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Enacted Self-Regulated Learning in Contextual Numeracy Tasks: A Qualitative Cross-Case Analysis Across Performance Levels

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ABSTRACT

Numeracy competence in contemporary assessment requires students to interpret contexts, reason quantitatively, and apply strategic problem solving. Although self-regulated learning (SRL) is widely linked to academic achievement, limited research has examined how regulatory processes are enacted during contextual numeracy tasks across performance levels. This qualitative cross-case study explored the manifestation of SRL in three students representing high, moderate, and low numeracy performance. Data were collected through written responses to four contextual numeracy tasks and semi-structured interviews. Analysis was guided by Zimmerman's cyclical SRL framework, focusing on forethought, performance, and self-reflection phases. Findings revealed clear differences in *regulatory depth. The high-performing student demonstrated coherent and adaptive regulation across phases, the moderate performer showed procedural regulation with limited monitoring, and the low performer exhibited surface-level planning and minimal persistence. Results indicate that numeracy performance is strongly associated with the sophistication of enacted regulatory processes rather than computational skill alone.*

Keywords: Self-regulated learning; Numeracy; Contextual mathematics assessment; Qualitative cross-case study; Zimmerman's cyclical SRL framework.

INTRODUCTION

Numeracy has become a central competence in 21st-century education, particularly as countries strengthen assessment systems that emphasize contextual mathematical reasoning. In Indonesia, numeracy is assessed through the Minimum Competency Assessment (MCA) implemented by the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia (Kemendikbud, 2021). Unlike traditional mathematics tests that focus primarily on procedural computation, MCA numeracy tasks require students to interpret information, analyze contextual data, and draw conclusions based on real-life situations. These demands indicate that numeracy involves higher-order thinking skills (HOTS), including reasoning, representation, evaluation, and interpretation within authentic contexts. Research shows that many students struggle not because of computational limitations but because of difficulties in contextual interpretation and in transferring mathematical concepts to real-world problems (Meryansumayeka et al., 2022; Siregar & Siregar, 2025). MCA numeracy fosters essential cognitive processes, including analyzing, evaluating, and constructing arguments, which are central to meaningful mathematical literacy aligned with real-life problem-solving (Nurandika & Ekawati, 2023; Supandi et al., 2022). These characteristics position numeracy as a complex cognitive competence that extends beyond procedural mastery toward contextual and analytical reasoning. Consequently, understanding the cognitive and regulatory processes that support students' engagement with contextual numeracy tasks becomes increasingly important in contemporary mathematics education.

One internal factor frequently associated with academic performance is Self-Regulated Learning (SRL). According to Barry J. Zimmerman, SRL refers to learners' ability to actively plan, monitor, and evaluate their cognitive and motivational processes during learning (Zimmerman, 1990). Students with strong SRL are believed to demonstrate better strategic behavior, persistence, and metacognitive awareness (Teng, 2022; Teng et al., 2024). In mathematics education, SRL has often been linked to improved problem-solving skills, conceptual understanding, and academic achievement (Granello et al., 2025). Theoretically, numeracy tasks that require interpretation and strategic thinking should benefit from strong self-regulation abilities (Blair & Razza, 2007; Distefano et al., 2021; Malanchini et al., 2019). Therefore, SRL is theoretically positioned as a critical internal resource that enables students to navigate the cognitive demands of contextual numeracy tasks. By supporting strategic planning, monitoring, and reflective evaluation, self-regulation may facilitate deeper engagement with complex mathematical reasoning processes.

However, empirical evidence reveals a more complex and inconsistent pattern. While several quantitative studies report significant positive correlations between SRL and mathematics achievement, others show weak or statistically insignificant relationships when numeracy is assessed through contextual problem-solving instruments (Cleary et al., 2020; Larbi et al., 2025). Overall, SRL appears to be a multifaceted process involving goal setting, strategic planning, and self-reflection that generally enhances math learning outcomes, but its impact may be less pronounced or more complex in real-world problem-solving contexts (Cleary et al., 2020; Fauzi & Widjajanti, 2018; Ha et al., 2023). This inconsistency suggests that the relationship between SRL and numeracy may depend on how regulatory processes are enacted in response to specific task demands. Contextual mathematical problems may require not only strategic regulation but also flexible conceptual transfer and situational reasoning. A closer examination of how students operationalize planning, monitoring, and reflection during authentic numeracy tasks is thus essential for clarifying this relationship.

Understanding self-regulated learning within the context of contextual numeracy requires examining how regulatory processes are enacted during authentic problem-solving rather than inferred from general learning behavior. Although SRL has been widely investigated across educational settings, its operation within assessment environments that demand interpretation, reasoning, and contextual transfer remains insufficiently articulated (Zakaria & Latif, 2023). Context-rich numeracy tasks place students in situations that require not only strategic planning and monitoring but also the ability to coordinate conceptual understanding with real-life information (Goos et al., 2013). Such demands may generate different regulatory patterns among students with varying levels of numeracy performance. Examining how high-, medium-, and low-performing students engage in planning, monitoring, and evaluation during contextual mathematical tasks enables a more nuanced conceptualization of SRL as situated cognition. Integrating analysis of written solution strategies with students' metacognitive reflections further allows for examination of the alignment or tension between regulatory intention and observable action within domain-specific reasoning.

Conceptually, this study is grounded in Zimmerman's cyclical SRL model, which consists of three interconnected phases: forethought (planning and goal setting), performance (self-monitoring and strategy implementation), and self-reflection (self-evaluation and adaptation) (Panadero, 2017; Silva & Marinho, 2024; Yang et al., 2024). Within contextual numeracy tasks, these phases are expected to manifest in how students interpret problem information, select solution strategies, monitor procedural and conceptual accuracy, and evaluate the coherence of their final answers. In this framework, numeracy performance is understood as the observable expression of underlying regulatory processes. SRL is thus positioned not as a determinant of achievement, but as a cognitive regulatory mechanism that shapes the quality of students' strategic engagement with contextual mathematical problems. Recent studies have increasingly emphasized the importance of examining self-regulated learning in context-specific tasks, particularly in numeracy and mathematical literacy (Liu et al., 2025; Waheed et al., 2025; Yang et al., 2024). These studies highlight that regulatory processes may vary depending on task complexity and contextual demands. Based on this framework, the present study addresses the following research questions: (1) How are self-regulated learning characteristics reflected in students' strategies when solving numeracy tasks? (2) What differences emerge among students with high, medium, and low numeracy performance in terms of planning, monitoring, and evaluation processes? (3) How do students' perceptions of self-regulation align with their observed problem-solving behavior? Accordingly, the objective of this research is to qualitatively explore the manifestation of self-regulated learning in students' numeracy task performance, thereby contributing a process-based perspective to the ongoing discourse on numeracy and learner autonomy.

RESEARCH METHOD

This study employed a qualitative descriptive design to explore how self-regulated learning (SRL) manifests during students' engagement with contextual numeracy tasks. A qualitative approach was considered appropriate because it allows in-depth exploration of students' cognitive and metacognitive strategies, particularly in relation to planning, monitoring, and evaluating their work. The study was guided by Zimmerman's cyclical SRL framework, which conceptualizes self-regulation as a dynamic process consisting of forethought, performance, and self-reflection phases (Zimmerman, 1990). Numeracy performance was analyzed as an observable representation of these regulatory processes.

The study was conducted at SMA Negeri 15 Takengon, Indonesia. Participants were eleventh-grade students who had previously participated in MCA simulation activities organized by the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia. Three students were selected through purposive sampling based on their numeracy test performance: ZA (high numeracy), NK (moderate numeracy), and IA (low numeracy). Categorization was determined by the total score on the administered numeracy test. The selection aimed to capture variation in regulatory strategies across performance levels rather than to generalize findings to a broader population. It is important to note that the purpose of selecting three participants was not to generalize findings, but to explore variations in regulatory processes across different performance levels.

The instrument consisted of four contextual numeracy tasks adapted from MCA simulation materials. The tasks covered four domains: Numbers, Algebra, Geometry and Measurement, and Data and Uncertainty. The items required students to use mathematical symbols and numbers appropriately, analyze contextual information presented in text, tables, or diagrams, and interpret results and formulate conclusions. Students completed the test individually within a structured classroom setting.

Semi-structured interviews were conducted after test completion. The interview protocol explored students' perceptions of independent learning, planning strategies before solving tasks, monitoring processes during problem-solving, evaluation strategies after completing tasks, and perceived difficulties and coping mechanisms. Each interview lasted approximately 30–45 minutes and was audio-recorded with participants' consent. Data collection was conducted in three stages: administration of the numeracy test, scoring and categorization of students' performance, and in-depth interviews with selected participants. Students' written responses were collected and analyzed before interviews to inform probing questions. This sequencing allowed triangulation between written work and verbal explanations.

Data were analyzed using thematic analysis guided by the SRL framework. The analysis followed three main steps. Data reduction involved transcribing interviews and identifying relevant excerpts on planning, monitoring, and evaluation. Data display included organizing students' written responses and interview excerpts into analytic matrices aligned with SRL phases. Conclusion drawing and verification involved interpreting patterns across high-, medium-, and low-numeracy performers to identify similarities and differences in regulatory strategies. Triangulation was conducted by comparing written test performance with interview narratives to ensure interpretive consistency. The analysis focused on describing observable regulatory behaviors rather than on causal inferences about the relationship between self-regulated learning and numeracy performance.

To systematically analyze the manifestation of self-regulated learning during numeracy problem-solving, a deductive thematic coding framework was developed based on Zimmerman's cyclical SRL model (forethought, performance, and self-reflection phases). Students' written responses and interview transcripts were coded according to observable regulatory behaviors aligned with each phase. The coding framework is presented in Table 1.

Table 1.

Coding Framework of SRL Phases and Observed Behaviors

SRL Phase	Operational Definition	Observed Behavioral Indicators in Test Responses	Indicators in Interview Responses
Forethought (Planning)	The process of setting goals, selecting strategies, and preparing approaches before task engagement	– Identifying known and unknown information in the problem. – Choosing which problem to solve first. – Writing initial representations or formulas.	– Describing strategy selection – Explaining how they decide which problem is easier/harder – Stating preparation steps before solving
Performance (Monitoring & Strategy Use)	The active implementation and monitoring of strategies during problem-solving	– Step-by-step procedural work – Revising calculations – Crossing out incorrect steps – Switching strategies when stuck	– Explaining difficulties encountered – Describing how they checked intermediate steps – Explaining adjustments made during solving
Self-Reflection (Evaluation)	The process of evaluating outcomes and reflecting on performance after completing the task	– Rechecking final answers – Writing concluding statements	– Explaining how they verified answers – Expressing confidence/doubt

SRL Phase	Operational Definition	Observed Behavioral Indicators in Test Responses	Indicators in Interview Responses
		– Correcting errors before submission	– Reflecting on mistakes and improvements

RESULTS

The analysis revealed distinct patterns of self-regulated learning (SRL) manifestation across students with high (ZA), medium (NK), and low (IA) numeracy performance. This analysis is descriptive in nature and does not aim to establish causal relationships between self-regulated learning and numeracy performance. Differences were particularly visible in how students enacted planning (forethought), monitoring (performance), and evaluation (self-reflection) phases during contextual problem-solving. The following figure presents the written solution produced by student ZA on Numeracy Task 1, which serves as the basis for examining the enacted self-regulated learning processes.

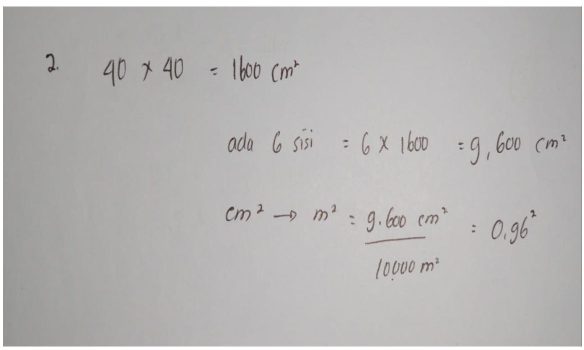

Figure 1. *Written response of student ZA on Numeracy Task 1.*

In Task 1, which represents the numbers element of numeracy, ZA's responses appeared structured and included observable instances of planning, monitoring, and verification, as evidenced by the written work and interview data. At the forethought phase, ZA correctly identified equal distribution as the core requirement and applied division to each quantity (240 ÷ 40, 270 ÷ 40, and 180 ÷ 40), indicating appropriate strategy selection and recognition of known and unknown values. During the performance phase, ZA monitored intermediate results and identified non-integer outcomes (6.75 and 4.5), signaling unequal distribution. Rather than stopping at fractional results, ZA adjusted the quantities to the nearest multiples of 40 by adding 10 cans of milk (280 ÷ 40 = 7) and 20 packs of cooking oil (200 ÷ 40 = 5). This strategic adjustment reflects active monitoring and adaptive reasoning grounded in divisibility concepts within the Numbers domain. In the self-reflection phase, ZA verified the revised quantities by recalculating the divisions to ensure equal distribution. Although no explicit written conclusion was provided, the recomputation indicates evaluative control over the final solution. Overall, ZA's response reflects coherent enactment of planning, monitoring, and evaluation processes characteristic of high numeracy performance in the Numbers element.

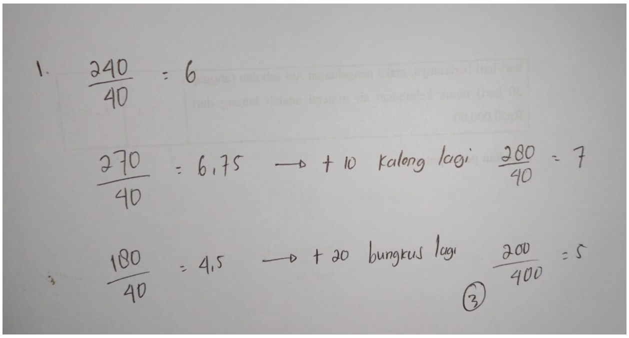

Figure 2. *Written response of student ZA on Numeracy Task 2.*

In Task 2, representing the Geometry and Measurement element, ZA's responses appeared structured and included observable instances of planning, monitoring, and verification based on the written work and interview data. At the forethought phase, ZA correctly identified the geometric structure of the problem by determining the area of one face of the cube (40 × 40 = 1,600 cm²) and recognizing that a cube consists of six faces. This indicates appropriate problem representation and strategic planning before proceeding to calculation. During the performance phase, ZA systematically calculated the total surface area (6 × 1,600 = 9,600 cm²) and converted it to square meters (9,600 ÷ 10,000 = 0.96 m²). The sequential execution of area calculation followed by unit conversion demonstrates procedural accuracy and dimensional consistency monitoring. ZA demonstrated conceptual understanding of area measurement and unit transformation within the geometric context. In the self-reflection phase, ZA verified the final unit conversion, ensuring that the result was expressed in square meters as required. Although the written response focused primarily on surface area calculation and did not explicitly articulate the final comparison with answer options, the structured progression of calculations indicates evaluative control. Overall, ZA's solution reflects coherent enactment of planning, monitoring, and evaluation processes characteristic of high performance in the Geometry and Measurement domain.

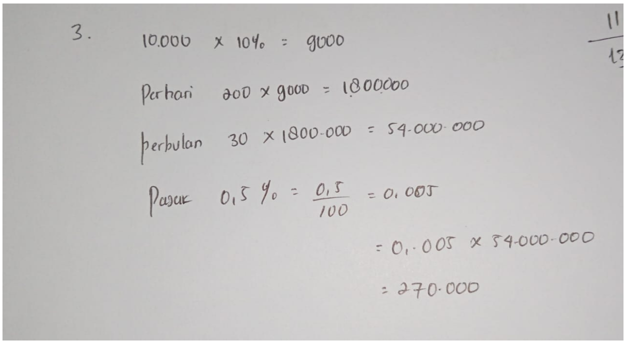

Figure 3. *Written response of student ZA on Numeracy Task 3.*

In Task 3, representing the Algebra element, ZA demonstrated coherent regulatory processes across the three SRL phases. At the forethought phase, ZA correctly identified the mathematical structure embedded in the contextual problem by determining the discounted price per portion (10,000 × 10% = 9,000). This indicates an appropriate interpretation of percentage reduction and a strategic representation of the problem before proceeding to larger-scale calculations. During the performance phase, ZA implemented a systematic sequence of calculations: determining daily revenue (200 × 9,000 = 1,800,000), extending it to monthly revenue (30 × 1,800,000 = 54,000,000), and converting the tax rate of 0,5% into decimal form (0.005) before calculating the final tax amount (0.005 × 54,000,000 = 270,000). The stepwise progression reflects procedural accuracy, monitoring of intermediate results, and consistent use of multiplicative reasoning characteristic of algebraic thinking. In the self-reflection phase, ZA verified the tax computation by explicitly converting the percentage to its decimal equivalent before multiplication, indicating awareness of the proportional reasoning requirements. Although no written explanatory statement accompanied the numerical solution, the structured and logically connected steps suggest evaluative control over the final answer. Overall, ZA's response reflects effective enactment of planning, monitoring, and evaluation processes within algebraic reasoning.

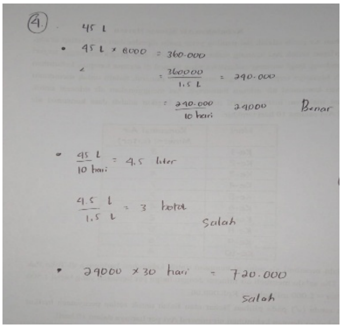

Figure 4. *Written response of student ZA on Numeracy Task 4.*

In Task 4, representing the Data and Uncertainty element, ZA's responses appeared structured and included observable instances of planning, monitoring, and verification, as evidenced by the written work and interview data. At the forethought phase, ZA first determined the total water consumption over 10 days (45 liters) and identified the price per 1.5-liter bottle (Rp 8,000), indicating appropriate interpretation of tabular data and relevant quantitative information before proceeding to the evaluation of the statements. During the performance phase, ZA systematically calculated total expenditure (45 × 8,000 = 360,000), converted it to the number of bottles (360,000 ÷ 1.5 = 240,000), and determined the average daily cost (240,000 ÷ 10 = 24,000). ZA then evaluated each statement by comparing computed values with the claims presented, marking the first statement as correct and the second and third statements as incorrect. The stepwise calculations reflect active monitoring and data interpretation within a contextual financial setting. In the self-reflection phase, ZA extended the reasoning to a monthly projection (24,000 × 30 = 720,000) to verify the plausibility of the final statement. This indicates evaluative control and consistency checking beyond minimal requirements. Overall, ZA's response reflects coherent enactment of planning, monitoring, and evaluation processes characteristic of high performance in data interpretation and quantitative reasoning under uncertainty.

Across the four numeracy elements, Numbers, Geometry and Measurement, Algebra, and Data and Uncertainty, ZA consistently demonstrated coherent enactment of the three phases of self-regulated learning. In the forethought phase, ZA systematically identified the mathematical structure underlying each task, whether through recognizing divisibility requirements, geometric representation, percentage relationships, or data aggregation. This indicates stable strategic planning and appropriate problem representation across varying contextual demands. During the performance phase, ZA exhibited strong monitoring behavior characterized by stepwise calculations, adjustment of intermediate results when necessary, and accurate unit or percentage conversions. Notably, ZA adapted strategies when encountering non-integer results in the Numbers task and verified dimensional consistency in Geometry and Measurement. In Algebra and Data tasks, ZA maintained structured multiplicative reasoning and proportional interpretation, suggesting flexible regulatory control across domains. In the self-reflection phase, ZA regularly rechecked computations and extended reasoning beyond minimal procedural completion, such as recalculating adjusted values and projecting monthly expenditures to verify conclusions. Although written explanations were concise, the logical sequencing of calculations indicates evaluative awareness embedded within domain-specific reasoning. Overall, ZA's responses reveal consistent alignment between regulatory intention and observable action, reflecting enacted self-regulation that supports high numeracy performance across mathematical elements.

To triangulate the findings from the written responses, interview data were analyzed to examine how ZA articulated self-regulated learning processes during problem-solving. The excerpt below highlights key statements related to forethought, performance, and self-reflection phases.

R	:	*In your opinion, is it important for a student to be able to regulate themselves while studying? Why?*	
ZA	:	*Yes, it is important because by regulating ourselves, we can manage our study time and other tasks more easily.*	*Forethought*
R	:	*Do you feel that you are an independent learner? Why?*	
ZA	:	*I do not think I am fully independent, because I often discuss with my friends and ask the teacher. However, when there is homework, I complete it independently.*	
R	:	*After completing a task or exam, how do you evaluate your learning results?*	
ZA	:	*I look at my scores. If they are not satisfactory, I study harder.*	*Self-Reflection*
R	:	*What information do you think is important in this problem?*	
ZA	:	*The most important information is what is given in the problem. For example, in question 1, there are 240 packs of instant noodles, 270 cans of milk, and 180 packs of cooking oil. After that, what is important is the instruction of the problem.*	*Forethought*
R	:	*How do you plan to solve the problem?*	
ZA	:	*I plan to solve the easiest questions first until all questions are answered.*	*Forethought*
R	:	*Did you encounter difficulties while solving the tasks? If yes, in which part and how did you overcome them?*	
ZA	:	*I found difficulties in questions 2 and 4. In question 2, I had difficulty understanding the information because there was too much information. But after taking some time, I was able to understand the instruction.*	*Performance*
R	:	*After getting an answer, how do you check your work?*	
ZA	:	*After I finish answering all questions, I recheck my answers to make sure there are no calculation errors.*	*Self-Reflection*
R	:	*If you realize there is a mistake, what do you do?*	
ZA	:	*If I notice a mistake before submitting, I redo the answer until I am sure it is correct.*	*Self-Reflection*
R	:	*Which question was the easiest and the most difficult? Why?*	
ZA	:	*The easiest were questions 1 and 3 because the information and instructions were clear. The most difficult were questions 2 and 4 because the answers were more complicated.*	

The interview data reinforce the patterns observed in ZA's written performance. During the forethought phase, ZA articulated deliberate task prioritization ("*solve the easiest questions first*") and identification of relevant information before solving, indicating structured strategic planning. In the performance phase, ZA acknowledged experiencing comprehension difficulties in more information-dense tasks but demonstrated persistence and cognitive monitoring until understanding was achieved. In the self-reflection phase, ZA systematically verified answers and corrected errors before submission, reflecting evaluative control. Additionally, ZA linked evaluation to academic outcomes by reviewing scores and adjusting future study effort. These responses align with the written evidence of recalculation, strategy adjustment, and consistency checking across tasks. The convergence between articulated regulatory strategies and observable solution behavior suggests strong alignment between perceived and enacted self-regulated learning processes. These interpretations are based on observable evidence and should not be taken as definitive indicators of overall self-regulated learning ability.

The following figures present the written responses of student NK, categorized as having moderate numeracy performance. These responses serve as the foundation for the subsequent SRL-based analysis.

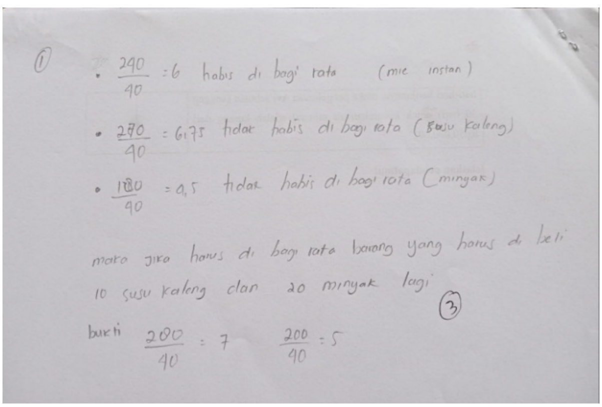

Figure 5. *Written response of student NK on Numeracy Task 1.*

In Task 1, representing the Numbers element, NK demonstrated partial enactment of self-regulated learning processes. At the forethought phase, NK correctly identified the need for equal distribution and performed division for each item (240 ÷ 40, 270 ÷ 40, and 180 ÷ 40). NK recognized which results were not evenly divisible, indicating initial awareness of the problem requirement. During the performance phase, NK identified that 270 and 180 could not be divided evenly by 40 and proposed adding 10 cans of milk and 20 packs of cooking oil. However, unlike ZA, NK's reasoning appeared more procedural than conceptual. The adjustment was made without explicitly demonstrating an understanding of the divisibility structure or verifying that the revised totals aligned consistently with distribution constraints. In the self-reflection phase, NK showed limited evidence of systematic verification. Although the adjusted totals were stated, recalculation and explicit confirmation were minimal. This suggests that monitoring occurred, but evaluative control was less strongly articulated than in the high-performing student. Overall, NK displayed functional planning and basic monitoring, but reflective depth and conceptual articulation were comparatively limited.

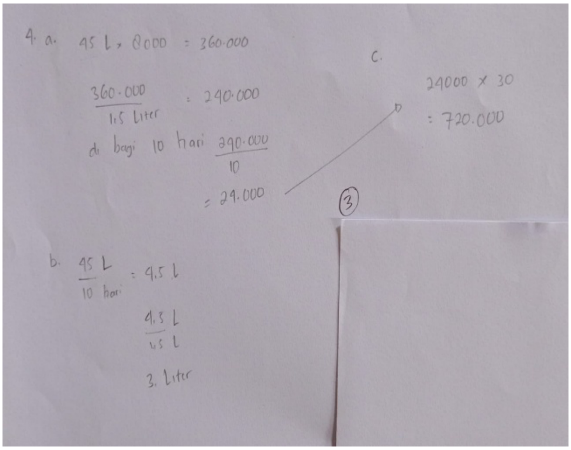

Figure 6. *Written response of student NK on Numeracy Task 2.*

In Task 4, representing the Data and Uncertainty element, NK demonstrated moderate regulatory engagement. At the forethought phase, NK identified total water consumption (45 liters) and correctly applied the price per bottle (Rp 8,000), indicating appropriate extraction of relevant data from the table. During the performance phase, NK calculated total expenditure (45 × 8,000 = 360,000) and determined average daily cost (240,000 ÷ 10 = 24,000). NK also attempted to evaluate the given statements and projected monthly expenditure (24,000 × 30 = 720,000). These steps indicate procedural monitoring and sequential reasoning. However, some intermediate calculations and representations were less systematically organized compared to ZA's work. In the self-reflection phase, NK marked statements as correct or incorrect but provided limited written justification. Verification appeared to rely primarily on numerical computation rather than deeper evaluative explanation.

Across the completed tasks, NK demonstrated the ability to initiate appropriate strategies and carry out procedural calculations. However, regulatory processes were more execution oriented than strategically adaptive. Monitoring occurred primarily at the computational level, while reflective articulation and conceptual justification were comparatively less explicit. Additionally, NK was unable to solve tasks 2 and 3, suggesting that regulatory stability decreased when contextual interpretation or algebraic reasoning demands increased. Overall, NK's responses reflect moderate numeracy performance, characterized by functional planning and procedural monitoring, with less consistent evaluative depth than the high-performing student.

To triangulate the findings from the written responses, interview data were analyzed to examine how NK articulated self-regulated learning processes during problem-solving. The excerpt below highlights key statements related to forethought, performance, and self-reflection phases.

R :	*In your opinion, is it important for a student to be able to regulate themselves in learning? Why?*	
NK :	*Yes, it is important because studying independently can improve learning outcomes to be more optimal.*	
R :	*Do you think you are an independent learner? Why?*	
NK :	*At home, yes, I am independent. But at school, I prefer discussing with my friends.*	
R :	*After completing an assignment or exam, how do you evaluate your learning outcomes?*	
NK :	*I look at my grades. If they are still unsatisfactory, I will study harder.*	*Self-Reflection*
R :	*What information do you think is important in the problem?*	
NK :	*I think the important information is the information given in the problem and the instructions that must be clear.*	*Forethought*
R :	*How do you plan to solve the problem?*	
NK :	*I plan to solve the easiest problems first until all questions are answered.*	*Forethought*
R :	*Are you confident in the calculations or steps you took? Why?*	
NK :	*I sometimes feel doubtful about calculations that I do myself. But for Question 1, I am very confident that it is correct.*	*Performance*
R :	*Did you encounter difficulties while working on the problems? If yes, in which part and how did you handle them?*	
NK :	*I had difficulties with Questions 2 and 3 because they were complicated and I could not answer them. But for Question 1, I was very confident, and the same with Question 4.*	*Performance*
R :	*After obtaining your answers, how did you check them?*	
NK :	*After finishing all the questions, I checked my answers one by one, in case there were calculation errors.*	*Self-Reflection*
R :	*If you find a mistake, what will you do to correct it?*	
NK :	*If I realize there is a mistake and the answers have not been submitted yet, I will redo them until I feel sure that they are correct.*	*Self-Reflection*

R	:	*Which question was the easiest and the most difficult? Why?*	
NK	:	*The easiest was Question 1 because the information and instructions were clear. Question 4 was manageable, but I was less confident in my answer. The most difficult were Questions 2 and 3 because they were too complicated and I could not answer them.*	*Forethought*

Based on the interview findings, NK's responses were analyzed using the self-regulated learning framework to identify manifestations of forethought, performance, and self-reflection processes. NK demonstrated basic planning awareness during task engagement. NK recognized that identifying given information and understanding task instructions were important components of solving the problems. NK also reported planning to solve the easiest problems first before attempting the others. This reflected procedural planning through task sequencing rather than explicit mathematical strategy formulation. NK's anticipation of task difficulty appeared to be influenced primarily by the clarity of information provided. NK perceived task 1 as easier because the instructions were clear, indicating that task interpretation guided planning decisions. However, NK did not articulate detailed strategic preparation or specific problem-solving approaches.

During task execution, NK demonstrated awareness of difficulty and uncertainty. NK reported feeling doubtful about calculations completed independently and acknowledged experiencing difficulty in tasks 2 and 3. However, NK recognized these challenges but did not demonstrate evidence of adaptive strategies or of restructuring the problem to overcome them. For task 1 and 4, NK expressed confidence in the answers. Monitoring appeared to operate primarily at an affective level (confidence versus doubt) rather than at a strategic cognitive level. There was limited indication of active revision, alternative strategy selection, or systematic adjustment during problem-solving.

NK reported checking answers one by one after completing all questions, indicating procedural verification behavior. NK also stated that if errors were identified before submission, NK would redo the answers until they felt confident about their correctness. This suggested the presence of evaluative control and corrective intention. However, NK's evaluation was primarily outcome-oriented. NK indicated reviewing grades to determine whether further study was necessary, suggesting that reflection focused more on results than on analyzing underlying problem-solving processes. Compared to higher-performing profiles, NK's reflective processes appeared present but less analytically elaborated. Overall, NK partially enacted self-regulated learning processes. Planning was present but general in nature. Monitoring was evident at an emotional level but limited in strategic adaptation. Evaluation behaviors were procedural and outcome-focused rather than deeply analytical. This regulatory profile aligned with NK's moderate numeracy performance, where self-regulatory processes were present but not consistently enacted at a metacognitive depth. While some regulatory behaviors were identified, the interpretation remains limited to observable data and may not fully capture internal cognitive processes.

The following figures present the written responses of student IA, categorized as having low numeracy performance. These responses serve as the foundation for the subsequent SRL-based analysis.

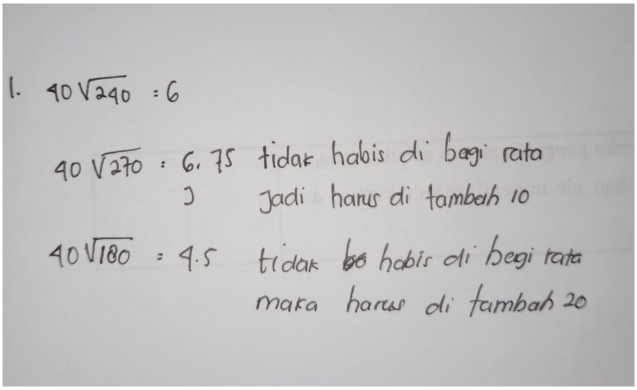

Figure 7. *Written response of student IA on Numeracy Task 1*

In Task 1, IA began by performing division directly (240 ÷ 40, 270 ÷ 40, and 180 ÷ 40). There was no explicit written indication that IA first restated the goal of equal distribution. Planning appeared implicit and procedural rather than explicitly articulated. IA seemed to recognize that the task required dividing each quantity by 40, but no evidence of anticipatory reasoning or structured problem representation was observed. During execution, IA identified that 270 ÷ 40 = 6.75 and 180 ÷ 40 = 4.5 were not evenly divisible. IA wrote that the quantities were "*not evenly divisible*" and concluded that additional items were required (adding 10 units and 20 units, respectively). This indicated awareness of divisibility constraints and basic monitoring of intermediate results. However, the reasoning remained computational and mechanical. IA did not explicitly justify why adding 10 and 20 would resolve the issue beyond making the numbers divisible by 40. The strategy used appeared reactive rather than adaptive. IA provided final adjusted quantities but did not include explicit verification steps or concluding statements. There was no written evidence of rechecking calculations or reflecting on the appropriateness of the solution. Evaluation processes appeared minimal and largely implicit.

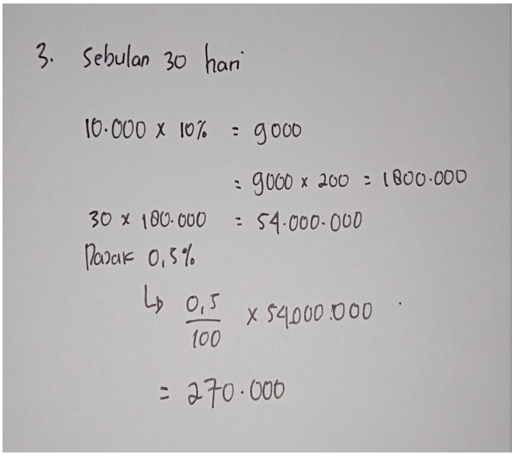

Figure 8. *Written response of student IA on Numeracy Task 3*

In Task 3, IA immediately calculated the discounted price (10,000 × 10%) and proceeded step by step, following the problem's structure. There was no explicit indication that IA outlined a plan before computing. Planning appeared sequential and directly guided by the order of information in the problem statement. IA calculated discounted price = 9,000, daily revenue = 9,000 × 200, monthly revenue = 30 × 1,800,000 and tax = 0.5% × 54,000,000. The solution followed a linear computational flow. Monitoring appeared focused on arithmetic progression rather than conceptual verification. IA did not show evidence of alternative reasoning or intermediate checking beyond completing the sequence of operations. IA provided the final tax amount (270,000) without additional explanation or verification. There was no written reflection, summary statement, or indication of checking the plausibility of the result. Evaluation behavior was therefore limited and procedural.

Overall, IA exhibited limited and largely procedural enactment of self-regulated learning processes in tasks 1 and 3. Planning was implicit and directly driven by numerical cues rather than by explicit strategic formulation. Monitoring focused primarily on basic arithmetic correctness, as IA recognized non-divisible results in task 1 and followed sequential calculations in task 3. However, there was minimal evidence of strategic adjustment, conceptual elaboration, or analytical verification. Evaluation processes were largely absent, as IA did not provide written justification or rechecking statements. Furthermore, IA was unable to provide solutions for tasks 2 and 4, indicating difficulty sustaining regulatory processes when tasks required more complex reasoning in geometry and data interpretation. This pattern reflected restricted metacognitive engagement and aligned with IA’s low numeracy performance.

To triangulate the findings from the written responses, interview data were analyzed to examine how IA articulated self-regulated learning processes during problem-solving. The excerpt below highlights key statements related to forethought, performance, and self-reflection phases.

R	:	*In your opinion, is it important for a student to be able to regulate themselves in learning? Why?*	
IA	:	*It is very important, because if we do not regulate ourselves in studying, then who will? By doing so, learning becomes more effective, and there is no pressure from others.*	*Forethought*
R	:	*Do you think you are an independent learner? Why?*	
IA	:	*I would not say I am fully independent, because I often discuss with my friends. However, I still try to study independently.*	
R	:	*After completing an assignment or exam, how do you evaluate your learning outcomes?*	
IA	:	*I look at my grades. If they are not satisfactory, I will study harder.*	*Self-Reflection*
R	:	*What information do you think is important in the problem?*	
IA	:	*The most important part is the instruction in the problem and the information related to it.*	*Forethought*
R	:	*How do you plan to solve the problem?*	
IA	:	*I plan to solve the easiest question first.*	*Forethought*
R	:	*Are you confident in the calculations or steps you took? Why?*	
IA	:	*I was not 100% confident, but I believed my answer was correct.*	*Performance*
R	:	*Did you encounter difficulties while working on the problems? If yes, in which part and how did you handle them?*	
IA	:	*Yes, I had difficulties in several questions, especially Question 2 about the surface area of a cube. I did not remember how to calculate it, so I could not answer it.*	*Performance*
R	:	*After obtaining your answer, how did you check it?*	
IA	:	*After finishing one question, I checked it again in case there were mistakes in the calculation.*	*Self-Reflection*
R	:	*If you found a mistake, what would you do?*	
IA	:	*If I realized there was a mistake and the answer had not been submitted yet, I would redo it until I felt sure it was correct.*	*Self-Reflection*
R	:	*Which question was the easiest and the most difficult? Why?*	
IA	:	*The easiest was Question 1 because it was only division. The most difficult was Question 2 because it was about the surface area of a rectangular prism, and I did not know how to solve it.*	*Forethought*

Based on the interview findings, IA's responses were analyzed using the self-regulated learning framework to identify manifestations of forethought, performance, and self-reflection processes. IA demonstrated general awareness of the importance of self-regulation in learning. IA emphasized that regulating oneself made learning more effective and reduced external pressure. However, when discussing task planning, IA reported solving the easiest question first without describing specific mathematical strategies. Planning appeared procedural and task-oriented rather than conceptually strategic. IA also identified instructions and given information as important, yet this recognition did not translate into structured strategic preparation for more complex tasks. IA reported uncertainty in the calculations, stating that it was not fully confident in the answers. This indicated affective monitoring of confidence levels. However, when encountering difficulty in task 2, IA stated that they did not remember the formula and therefore could not answer the problem. There was no evidence of adaptive strategy use, alternative reasoning attempts, or persistence in restructuring the problem. Monitoring appeared limited to recognizing a lack of knowledge rather than regulating cognition to overcome it. IA reported checking answers after completing each question and stated willingness to redo answers if mistakes were identified before submission. This reflected procedural evaluative behavior. Additionally, IA indicated reviewing grades to determine whether further study was needed, suggesting outcome-based reflection. However, reflective processes remained focused on correctness rather than analysis of underlying conceptual understanding. There was limited evidence of deeper metacognitive evaluation. Overall, IA exhibited surface-level self-regulated learning processes. Planning was general and sequential. Monitoring was primarily effective, characterized by uncertainty and recognition of knowledge gaps. Evaluation behaviors were procedural and outcome-oriented. When facing conceptual difficulty, IA disengaged rather than adapting strategies, which aligned with IA's inability to answer tasks 2 and 4. The absence of explicit evidence in written or verbal responses does not necessarily indicate the absence of self-regulated learning processes.

DISCUSSION AND CONCLUSION

Across the three participants, distinct patterns of self-regulated learning enactment were observed in relation to numeracy performance levels. ZA demonstrated coherent, strategically integrated regulatory processes across the forethought, performance, and self-reflection phases, including adaptive adjustment when encountering non-integer results and systematic verification of solutions. NK exhibited partial regulatory engagement, characterized by procedural planning and affective monitoring, but showed limited strategic adaptation when faced with complex tasks. IA demonstrated largely surface-level regulation, with planning driven by task sequencing, monitoring centered on confidence rather than cognitive strategy, and minimal persistence when conceptual understanding was insufficient. Notably, while all participants expressed awareness of the importance of self-regulation during interviews, the depth and consistency of regulatory enactment during task performance differed substantially. These cross-case patterns suggested that variations in numeracy performance were associated not merely with computational ability but with differences in the quality and sophistication of self-regulated learning processes. This comparative synthesis provides the basis for further discussion regarding how regulatory depth influences numeracy competence. However, these patterns should be interpreted cautiously, as they are based on a small number of cases and descriptive qualitative analysis.

The findings of this study can be interpreted through the lens of Zimmerman's self-regulated learning framework, which conceptualizes learning as a cyclical process consisting of forethought, performance, and self-reflection phases. Consistent with this model, the present results indicated that differences in numeracy performance were associated with variations in the depth and coherence of regulatory enactment across these phases. ZA demonstrated integrated and adaptive regulation, reflecting the cyclical and strategic characteristics described by Zimmerman, in which planning informed strategy use, and evaluation supported adjustment. In contrast, NK exhibited partial regulation that remained largely procedural, while IA demonstrated surface-level engagement with limited adaptive control when facing conceptual challenges. These findings aligned with broader research indicating that numeracy competence is influenced not only by mathematical knowledge but also significantly by the sophistication of learners' self-regulatory processes. Empirical studies have shown that self-regulation predicts initial mathematics achievement and growth, even after controlling for cognitive ability (Blair et al., 2015; DeFlorio et al., 2018). Furthermore, higher levels of self-regulation have been positively associated with mathematical competence and problem-solving effectiveness across age groups (Quis et al., 2019; Tagle & Apohen, 2025; Wiguna et al., 2024). In this study, ZA's adaptive monitoring and systematic verification reflected the kind of regulatory depth that previous research has linked to stronger mathematical performance. Conversely, NK and IA exhibited regulatory patterns more consistent with outcome-oriented or surface-level control, which may limit sustained conceptual reasoning.

Additionally, research has shown that self-regulation interacts with motivational beliefs and metacognitive skills, with students with stronger regulatory capacities applying more effective strategies and demonstrating higher self-efficacy (Throndsen, 2011). The present findings supported this perspective, as confidence, persistence, and strategic adjustment differentiated the high performer from the moderate and low performers. Interventions integrating both mathematical skills and self-regulatory training have also shown promise in enhancing numeracy outcomes (DeFlorio et al., 2018; Warmansyah et al., 2023), suggesting that regulatory depth may moderate the impact of instruction. Overall, these converging findings reinforced the argument that fostering self-regulatory processes alongside mathematical knowledge is crucial for improving numeracy competence across performance levels (Malanchini et al., 2019; Rivera & Canoy, 2025).

These findings further converged with empirical evidence indicating that higher academic performance was associated with more sophisticated and adaptive self-regulated learning processes. Prior research has emphasized that successful learners engage not only in strategic planning but also in continuous monitoring and reflective evaluation, particularly when facing cognitively demanding tasks (Broadbent, 2017; Liu et al., 2025; Theobald, 2021; Waheed et al., 2025). In numeracy contexts, adaptive regulation, such as revising strategies and restructuring problem representations, has consistently differentiated high from low performers. Moreover, executive function, a core component of self-regulation, has been consistently shown to predict early numeracy development across diverse contexts, underscoring its foundational role in mathematical learning (Distefano et al., 2021). Self-regulation has also been found to mediate the relationship between numerical literacy and broader academic achievement, suggesting that the capacity to strategically manage learning processes enhances numeracy success (Warnaningtyas et al., 2025). Additionally, adaptive instructional environments that tailor difficulty to learners' performance improve efficiency and reduce mathematics anxiety, particularly among students with stronger prior knowledge (Vanbecelaere et al., 2020). However, research also cautions that adaptive environments alone may not automatically transform underlying self-regulatory profiles without explicit regulatory support (Abouelenein et al., 2025). Collectively, these findings reinforce the interpretation that adaptive regulation functions as a critical mechanism that distinguishes high- and low-numeracy performers through strategic flexibility and effective self-management of learning processes. The present cross-case comparison substantiated this distinction: ZA demonstrated cyclical and adaptive regulation, whereas NK and IA exhibited diminishing strategic control as conceptual demands increased. Moreover, the tendency of lower-performing students to rely on outcome-oriented rather than process-oriented reflection was mirrored in NK and IA’s responses. Collectively, these patterns strengthened the argument that regulatory depth, rather than procedural accuracy alone, played a pivotal role in numeracy achievement.

The patterns identified in this study suggested important pedagogical implications for mathematics instruction. The findings indicated that fostering numeracy competence required more than strengthening computational skills; it required explicit scaffolding of regulatory processes within the context of problem-solving tasks. Students with moderate and low performance demonstrated awareness of self-regulation at a declarative level, yet they struggled to enact strategic adaptation when confronted with conceptual difficulty. This implied that classroom practices should not only encourage independence but also model how to interpret contextual information, anticipate potential obstacles, and revise strategies when initial approaches prove insufficient. Embedding structured metacognitive prompts, guided reflection sessions, and task debriefings into numeracy instruction may support deeper regulatory engagement. Such approaches could help students transition from procedural execution toward strategic and adaptive reasoning.

Despite its contributions, this study should be interpreted with caution. The analysis was based on a small number of participants across three performance levels, limiting the generalizability of the findings. It is also important to acknowledge that the interpretation of self-regulated learning in this study relies on observable behaviors from written responses and interviews. Some regulatory processes may remain internal and not fully captured in the data. While triangulation between written responses and interviews strengthened interpretive validity, the data relied on retrospective self-reports that may not have fully reflected real-time cognitive processes. Nevertheless, the depth of qualitative analysis provided insight into how regulatory processes operated within authentic numeracy tasks. These considerations framed the conclusion by emphasizing the conditional and situated nature of self-regulated learning in relation to numeracy performance.

This study concluded that differences in numeracy performance appeared to be related to how self-regulated learning processes were enacted in the observed cases. While all participants recognized the importance of self-regulation, only the high-performing student consistently demonstrated adaptive, cyclical regulatory processes during contextual problem-solving. Moderate performance was characterized by procedural regulation with limited strategic adaptation, whereas low performance reflected surface-level engagement and reduced persistence when conceptual demands increased. These findings indicated that numeracy competence was not merely a function of computational ability but was strongly influenced by the sophistication of regulatory processes enacted during task completion.

The study underscored the importance of positioning self-regulated learning as an enacted cognitive mechanism embedded within domain-specific reasoning rather than as a generalized learner attribute. Variations in regulatory depth shaped how students interpreted contextual information, responded to difficulty, and evaluated solution validity. Understanding these regulatory differences provided a process-oriented perspective on numeracy achievement and contributed to ongoing discussions regarding the interaction between metacognition and mathematical literacy in assessment contexts.

Future research should extend this investigation across broader and more diverse educational contexts to examine whether similar regulatory patterns emerge among students with different socio-academic backgrounds. Incorporating mixed-method designs or real-time process-tracing approaches, such as think-aloud protocols, may provide deeper insight into how regulatory processes unfold during contextual numeracy tasks. Additionally, experimental studies examining metacognitive scaffolding interventions could determine whether strengthening adaptive planning, monitoring, and evaluation directly enhances numeracy performance. Refining assessment instruments to distinguish between perceived and enacted self-regulated learning would also contribute to greater theoretical clarity in understanding the relationship between regulatory processes and mathematical literacy.

This study has several limitations. First, using a single participant per performance level limits the generalizability of the findings. Second, numeracy performance was not measured with an independent standardized instrument, which may compromise the robustness of the performance categorization. Third, the interpretation of self-regulated learning was based on observable data, which may not fully capture internal cognitive processes.

AI Disclosure Statement

The authors used AI-assisted tools during the preparation of this manuscript. Consensus AI was utilized to assist in identifying relevant scholarly literature, Grammarly was used for language proofreading and grammar improvement, and ChatGPT was used to support language refinement, drafting assistance, and improvement of academic writing clarity. All content, interpretations, analyses, and conclusions were independently reviewed and verified by the authors. The authors remain fully responsible for the accuracy, originality, ethical integrity, citations, and intellectual content of this manuscript.

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