AN EXPLORATORY MIXED METHODS STUDY OF STUDENTS' CRITICAL THINKING BASED ON SELF-REGULATED LEARNING IN NUMERACY LITERACY PROBLEM SOLVING

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ARTICLE INFO	ABSTRACT
	This study aims to explore students' critical thinking skills in solving numeracy literacy problems based on their levels of Self-Regulated Learning (SRL). The research employed a mixed-methods approach with an explanatory sequential design, involving 36 eleventh-grade students from a public senior high school in Bojonegoro. Quantitative data were collected through SRL questionnaires and numeracy literacy tests, while qualitative data were obtained from in-depth interviews with students representing high, medium, and low SRL categories. The results reveal a consistent relationship between SRL levels and critical thinking abilities. Students with high SRL demonstrated systematic and reflective critical thinking, encompassing interpretation, analysis, evaluation, and reflection. Students with medium SRL showed adequate analytical and evaluative abilities but were less consistent in reflection, while students with low SRL tended to rely on procedural thinking without re-evaluating their results. This study contributes by providing an exploratory mixed-methods profile of students' critical thinking across different levels of self-regulated learning in numeracy literacy problem solving. The findings suggest that enhancing self-regulation plays a vital role in fostering students' critical thinking, particularly in numeracy literacy tasks that require logical reasoning and metacognitive reflection.

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INTRODUCTION

Critical thinking skills are one of the key skills that students must possess in order to face the challenges of 21st-century education. These skills require students to be able to assess information rationally, analyze arguments, make logical inferences, and evaluate decisions based on relevant evidence. Critical thinking in mathematics is increasingly conceptualized as a process-oriented construct that involves interpretation, analysis, evaluation, and reflection rather than merely producing correct answers (Monteleone et al., 2023).Critical thinking is not only needed in an academic context, but also in everyday life in order to solve complex problems independently (Okolie et al., 2022). In the context of Indonesian education, critical thinking skills are an integral

part of developing higher-order thinking skills (HOTS), which are the primary focus of the independent curriculum (Asmara & Septiana, 2024).

However, national and international assessments show that Indonesian students' critical thinking skills remain low. The 2022 PISA results report that Indonesia's average mathematics score is only 366, far below the OECD average of 472 (OECD, 2022). This condition indicates that many students are still unable to apply logical reasoning to interpret quantitative information and solve problems based on real-life contexts. Satria et al. (2025) emphasize that low critical thinking skills are related to poor learning quality, which does not encourage reflective and analytical thinking processes. This has a direct impact on students' numeracy literacy skills, which are still limited to the application of routine procedures without deep conceptual understanding.

Numeracy literacy itself is not just the ability to count, but also includes the skills to understand, interpret, and use mathematical representations in real contexts. (Fajriyah, 2022; Khakima et al., 2021). In solving numeracy problems, students are required to interpret data, choose the right strategy, and evaluate the resulting solution. Jannah & Hayati (2024) state that critical thinking skills are the main foundation of numeracy literacy because they require students to connect mathematical concepts with real-life contexts. Conversely, when students are not trained to think critically, the process of solving numeracy problems tends to be mechanistic and not based on reasoning (Rohim & Rofiki, 2024). Studies in senior high school contexts have also demonstrated that mathematical learning activities can stimulate students' critical thinking through structured problem-solving stages (Setiana et al., 2021).

Various studies show that one of the internal factors that influences critical thinking skills is Self-Regulated Learning (SRL). According to Zimmerman in (Navyola, 2022), SRL is the ability of students to consciously manage their learning process through planning, implementing strategies, and reflecting on results. Students with high SRL usually have strong metacognitive awareness, are able to monitor their learning progress, and take the initiative to correct strategic errors. Ghimby (2022) Found that SRL had a positive effect on students' critical thinking skills and learning outcomes. Similar results were reported by Rahmawati & Alaydrus (2021), This explains that students with high self-regulation are more active in the process of reflection and evaluation, so that their critical thinking skills develop better. Recent bibliometric evidence indicates that research on self-regulated learning in mathematics has grown substantially, yet most studies remain outcome-oriented, with limited attention to students' cognitive processes during problem solving (Marchy et al., 2023).

However, most research on SRL and critical thinking is still quantitative and correlational in nature. This approach does show the relationship between variables, but it does not describe in depth how differences in SRL levels affect the way students think when solving numeracy problems (Roslinda et al., 2022). Meanwhile, exploratory research describing critical thinking profiles based on SRL categories (high, medium, and low) remains relatively rare. In fact, this approach is crucial for understanding the cognitive and metacognitive processes that occur during real problem-solving (Herdianti & Muntazhimah, 2023).

However, most existing studies on the relationship between self-regulated learning and critical thinking remain predominantly quantitative and correlational, focusing on outcome measures rather than the underlying thinking processes. As a result, there is limited empirical evidence explaining how differences in SRL levels shape students' critical thinking processes when solving numeracy literacy problems. In particular, research that integrates quantitative classification of SRL with qualitative exploration of students' reasoning across high, medium, and low SRL categories in numeracy contexts is still scarce. Addressing this gap, the present study adopts an exploratory mixed-methods approach to examine students' critical thinking profiles based on their SRL levels in numeracy literacy problem solving.

METHOD

This study employs a mixed-methods approach with an explanatory sequential design. This approach begins with quantitative data collection through the distribution of Self-Regulated Learning (SRL) questionnaires and numeracy literacy tests, followed by qualitative data collection through in-depth interviews with selected students. This strategy aims to gain a comprehensive understanding of the variations in students' critical thinking abilities in solving numeracy problems in terms of their level of self-regulation (Creswell, 2017; Nasution, 2023; Saleh, 2023).

Research Subject and Location

The research was conducted at a public high school in Bojonegoro City, East Java. This school was purposively selected because it had implemented numeracy-based learning and authentic assessment in mathematics classes. The research subjects consisted of 36 eleventh-grade students, all of whom were respondents to questionnaires and tests in the quantitative stage. For the qualitative stage, six students (two each from the high, medium, and low SRL categories) were selected as interview participants based on the results of SRL score categorization and numeracy literacy test results.

Research Instruments

Three main instruments were used in this study, namely the SRL questionnaire, numeracy literacy test, and mathematical critical thinking interview guidelines.

1. Self-Regulated Learning (SRL) Questionnaire

This instrument was adapted from Zimmerman's SRL model and developed contextually for high school students. The questionnaire consists of 27 positive and negative statements that measure three main components of SRL, namely:
(a) Forethought (planning and setting learning objectives),
(b) Performance control (learning strategies and progress monitoring), and
(c) Self-reflection (self-evaluation and strategy improvement).
Each item was answered using a 5-point Likert scale (Always, Often, Sometimes, Rarely, and Never). The reliability of the instrument was tested using Cronbach's alpha coefficient.

Students' Self-Regulated Learning (SRL) scores were obtained by summing responses across all questionnaire items. The questionnaire consisted of 27 items rated on a five-point Likert scale, resulting in a possible total score range of 27 to 135. To classify students' SRL levels, a statistical categorization method based on the mean and standard deviation was employed. Students with SRL scores greater than or equal to (mean + 1 SD) were categorized as having high SRL, those with scores between (mean − 1 SD) and (mean + 1 SD) were categorized as having medium SRL, and those with scores less than or equal to (mean − 1 SD) were categorized as having low SRL. This categorization approach is commonly used in educational research to distinguish levels of self-regulated learning (Roslinda et al., 2022).

2. Numeracy Literacy Test

This open-ended test is based on the PISA 2022 indicators (OECD, 2022) for real-life contexts. There are three questions with contexts: (1) determining the optimal selling price of a product, (2) analyzing discount promotion decisions, and (3) the efficiency of school garden land. Each question requires the ability to interpret situations, choose strategies, perform calculations, and evaluate results in authentic contexts. The test results are used to assess numeracy literacy skills and identify students' critical thinking tendencies (Pratiwi et al., 2024).

3. Guidelines for Critical Thinking Interviews in Mathematics

Critical Thinking Interview Guidelines: These interview guidelines are designed to explore in depth the critical thinking processes of students based on the results of descriptive tests. The questions are compiled based on Facionematis' critical thinking indicators (Fauziah & Kuntoro, 2022), Covering aspects of interpretation, analysis, evaluation, and reflection-explanation. The main questions are directly related to the context of the question, for example, how students interpret the relationship between price and number of buyers, assess the effectiveness of discount strategies, or consider the efficiency of garden design.

Data Collection Procedures

In the first stage, the SRL questionnaire was distributed to all 36 students to obtain their self-regulation scores. These scores were categorized into three levels (high, medium, and low) based on the data distribution range (Ghimby, 2022; Roslinda et al., 2022).

In the second stage, all students took a numeracy literacy test to measure their critical thinking skills in a contextual setting.

In the third stage, in-depth interviews were conducted with six students selected from each SRL category. The interviews were semi-structured, recorded, transcribed, and confirmed with the participants (member checking) to ensure data accuracy.

Data Analysis

Data analysis was conducted in stages according to an explanatory sequential design.

Quantitative Analysis: SRL data and numeracy literacy scores were analyzed descriptively using means, standard deviations, and categorization.

Qualitative Analysis: Interview transcripts were analyzed using a thematic analysis approach, including data reduction, data presentation, and conclusion drawing (Creswell, 2017). The coding process is directed at four indicators of critical thinking (interpretation, analysis, evaluation, and reflection).

Triangulation: Interview results are compared with test results and questionnaire data to ensure consistency between sources (Nasution, 2023).

Data Validity and Credibility

Data validity is maintained through triangulation of sources and techniques, member checking, and peer debriefing with supervisors and fellow researchers. The content validity of the instruments is obtained through expert judgment, while the reliability of the questionnaires is tested through internal consistency tests.

RESULTS

The results of the Self-Regulated Learning (SRL) questionnaire data processing show variations in the level of self-regulation of students in managing and controlling their learning processes. Based on the analysis of 36 respondents, the mean SRL score was 87.58 with a standard deviation of 3.39. Based on these calculations, students with an SRL score ≥ 90.97 were categorized as having high SRL, students with scores between 84.19 and 90.96 were categorized as having moderate SRL, and students with scores < 84.19 were categorized as having low SRL. The distribution of student categories is presented in Table 1.

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Tabel 1. Distribution of Students' Self-Regulated Learning Levels

SRL Category	Number of Students	Percentage (%)
High	6	16.7 %
Currently	22	61.1 %
Low	8	22.2 %
Total	36	100 %

As shown in the table, the majority of students are in the moderate category with a proportion of 61.1%. This condition shows that most students are aware of the need to manage their learning process, but this ability has not been consistently applied in every learning activity. Students in this category tend to be able to develop learning plans, but still often experience difficulties in maintaining focus, managing time, and evaluating learning outcomes independently. They demonstrate self-regulation at the level of performance control, but are not yet fully strong in the aspect of self-reflection, which includes evaluation and improvement of learning strategies.

Meanwhile, 16.7% of students were classified as high, indicating that they have a good level of learning independence and metacognitive awareness. Students in this category demonstrate the habit of planning learning objectives, setting short-term targets, and actively monitoring progress and evaluating results. They have strong self-control over external distractions and consciously adjust their learning strategies when encountering difficulties. These findings are in line with the results of studies by Rahmawati & Alaydrus (2021) and Ghimby (2022), which state that students with high SRL generally exhibit reflective learning behavior, can evaluate their own thinking processes, and are more oriented towards achieving long-term learning goals.

In contrast, 22.2% of students were classified as low, indicating weak self-regulation abilities in the learning process. Students in this category tend to be reactive rather than proactive. They study only when there are external demands such as exams or assignments, and rarely reflect on their mistakes. The initial interview results also showed that students with low SRL often rely on the help of friends or teachers to understand the material. This pattern illustrates low metacognitive awareness and motivational control, which is consistent with the findings Navyola (2022), this confirms that low SRL is often associated with passive learning strategies and high dependence on external guidance.

In general, this distribution shows that the SRL abilities of students in the high schools where this research was conducted are still diverse, with a dominant tendency toward moderate levels. This condition reflects that most students already understand the importance of managing the learning process, but do not yet fully possess the reflective habit of continuously improving and evaluating their learning methods. Asmara & Septiana (2024) states that immature self-regulation skills can hinder the development of higher-order thinking skills because students are not yet able to assess and control their own thinking strategies.

These results form an essential basis for the next stage of analysis. Differences in SRL levels among students are thought to influence differences in their critical thinking patterns when solving numeracy literacy problems. Students with high SRL are expected to have more systematic and reflective critical thinking skills because they are accustomed to reviewing the decisions they make while learning. Conversely, students with low SRL are likely to show impulsive thinking and be oriented towards the final result without considering the logical reasons behind their answers. Therefore, three students representing each SRL category were selected as interview subjects to explore in depth the relationship between self-regulation and critical thinking skills in the context of numeracy problem solving.

Numeracy Literacy Test Results

Numeracy literacy tests were given to three students representing each category of Self-Regulated Learning (SRL), namely high, medium, and low. These tests served to assess the students' ability to understand, reason, and solve contextual problems based on mathematical calculations. The scores of the three students are shown in the following table.

Tabel 2. Numeracy Literacy Test Scores

SRL Category	Score	Description
High	92	Demonstrating a deep understanding of the context of the question, accurate calculations, and systematic logical reasoning.
Currently	83	Able to understand most of the context and solve problems correctly, but there are still minor conceptual errors.
Low	50	Limited understanding of context, a tendency toward procedural solutions, and numerous errors in calculations and logical reasoning..

From Table 2 above, there is a clear difference between SRL categories and numeracy literacy test results. Students with high SRL obtained the highest scores (92), followed by students with moderate SRL (83), and students with low SRL (50). This shows a tendency that the higher the level of self-regulation of students, the better their ability to understand the context and develop problem-solving strategies.

Students with high SRL demonstrate accuracy in calculations, the ability to connect context with mathematical concepts, and justify results with logical reasoning. Conversely, students with low SRL appear to have difficulty understanding the core of the problem, often make mistakes in applying formulas, and do not double-check their calculations. These results support the findings Pratiwi et al. (2024) This states that self-regulation has a significant influence on mathematical thinking and numeracy problem-solving abilities. Thus, these test results provide a starting point for understanding differences in students' critical thinking skills based on SRL categories.

Critical Thinking Interview Results

1. Subject High SRL

The interview results show that students with high SRL categories have systematic and reflective critical thinking skills. At the interpretation stage, subjects are able to clearly understand the context of the problem and interpret information meaningfully. For example, when reading the first question, he stated: "I understand that I have to find a price that will maximize Rani's income. So, I made a table to see the relationship between price and the number of buyers." This statement demonstrates the subject's ability to identify the relationship between variables and the objective of the problem, an important characteristic of critical thinking (Okolie et al., 2022).

During the analysis stage, the subject systematically organized the steps through gradual calculations and table creation. The subject also demonstrated evaluation skills, namely comparing income results for each price variation to find the maximum point. He stated: "I see from the changes in the table that the results decline after the price reaches Rp8,000. This means that Rp8,000 is the maximum income. "In addition, the subject also demonstrated good reflection and inference. He realized that there was potential for improvement in the presentation of logical reasons and reassessed the effectiveness of the solution he had made:" Maybe I will write my answer more precisely and my reasons more logically."

This pattern illustrates that students with high SRL are capable of metacognitive regulation in their thinking processes. This is in line with the opinions of Ghimby (2022) and Roslinda et al. (2022) that individuals with high SRL tend to be able to control their thinking strategies and evaluate their own decisions. Thus, the critical thinking skills of students with high SRL are not only evident in the final results but also in the analytical and reflective processes that accompany them.

2. Subjek Medium SRL

Students with SRL demonstrate fairly good critical thinking skills, but they are not yet consistent. They understand the context of the question correctly and are able to organize logical calculation steps, although these are still procedural in nature. At the interpretation stage, the subject understands the purpose of the question, as seen in their statement: "Rani wants to know what price will give her the most income." The subject also demonstrates analytical skills by comparing the results of the income table they have compiled: "When the price is Rp 8,000, there are 60 buyers, and the income is Rp 480,000. When the price is Rp 8,500, there are 55 buyers, and the income is Rp 467,500. After that, it actually decreases."

However, SRL students' evaluation and reflection skills are still limited. They rarely review their results in depth and do not show initiative to improve their problem-solving steps. For example, when asked about improvements, they answer, "None."

However, in the context of promotions, this subject was able to distinguish between two types of discounts through simple mathematical modeling and understand why many people misinterpret sequential promotions. These findings indicate that SRL students have the potential for critical thinking, but still need external stimuli to activate self-reflection (Fauziah & Kuntoro, 2022; Herdianti & Muntazhimah, 2023).

3. Subjek Low SRL

Unlike the previous two categories, students with low SRL demonstrated limited critical thinking skills at a superficial level. At the interpretation stage, the subject was unable to understand the context of the problem well, as seen in his statement: "The question is difficult." At the analysis stage, the subject did not develop a solution strategy but relied on examples in the book. He said, "Maybe I'll look at examples in the book that are similar."

In addition, evaluation and reflection skills were also very low. The subjects admitted that they were unsure of their answers and did not try to review their thought processes. They said, "I don't know, because I'm not sure."

This limitation indicates weak metacognitive and self-regulation abilities. Students with low SRL are unable to control their own thinking processes and tend to give up when faced with challenging problems. This condition is in line with the findings of Navyola (2022) and Sa'diyah & Aini (2022), that low SRL has direct implications for the lack of reflective initiative and critical thinking skills in the context of mathematics learning.

4. Comparative Analysis between SRL Categories

The comparison between the three subjects shows a consistent pattern: the higher the SRL level, the better the students' critical thinking skills. Students with high SRL demonstrated all four indicators of critical thinking (interpretation, analysis, evaluation, and reflection). Conversely, students with moderate SRL only achieved simple analysis and evaluation, while students with low SRL stopped at incomplete interpretation.

These findings support the results of the study Rahmawati & Alaydrus (2021), SRL plays an important role in directing students' metacognitive awareness, which ultimately affects the quality

of critical thinking. The better students' self-regulation skills are, the greater their ability to control thinking strategies, verify information, and evaluate decisions in numeracy literacy problem solving.

DISCUSSION

The findings of this study indicate a consistent pattern between students' levels of Self-Regulated Learning (SRL) and their critical thinking skills in solving numeracy literacy problems. Students with higher SRL demonstrated more systematic, reflective, and metacognitively driven thinking processes, whereas students with lower SRL tended to rely on procedural approaches without evaluating the accuracy or relevance of their solutions. However, these findings should be interpreted cautiously, given the exploratory nature of the study and its limited sample size.

The observed pattern aligns with Zimmerman's conception of SRL as an active process involving planning, monitoring, and reflection, which supports learners in regulating both their learning strategies and cognitive processes (Navyola, 2022). Students with high SRL in this study consistently engaged in self-monitoring and self-evaluation, such as rechecking calculations and reassessing solution strategies. This is consistent with previous findings indicating that SRL is closely related to metacognitive activities that underpin critical thinking (Ansari et al., 2021; Ghimby, 2022; Roslinda et al., 2022). Nevertheless, it is important to emphasize that the present study does not establish a causal relationship between SRL and critical thinking. Rather, SRL should be viewed as a facilitating condition that supports reflective thinking processes.

Alternative interpretations should also be considered. Differences in critical thinking performance may not solely reflect variations in SRL levels. Factors such as prior mathematical knowledge, learning motivation, classroom instructional practices, or students' familiarity with contextual numeracy problems may also have influenced the results. For instance, students categorized as having high SRL may have previously experienced learning environments that emphasized problem-based or reflective learning, which could independently enhance their critical thinking abilities (Asmara & Septiana, 2024). Therefore, SRL should be understood as one of several interacting factors rather than the sole determinant of critical thinking skills.

The findings also suggest that critical thinking is not a unitary skill but develops in levels corresponding to students' reflective awareness. Students with moderate SRL were able to perform analysis and comparison but showed limited evaluation and reflection. This pattern supports the view that immature self-regulation may result in intermediate levels of critical thinking that are analytical but not yet fully reflective (Fauziah & Kuntoro, 2022). In contrast, students with low SRL often failed to engage in metacognitive monitoring, causing their thinking processes to stop at surface-level interpretation, a pattern also reported in studies on self-regulated learning in mathematics contexts (Herdianti & Muntazhimah, 2023).

From a contextual perspective, this study reinforces the role of numeracy literacy tasks as a meaningful medium for examining students' critical thinking processes. Numeracy-based problems require students to interpret real-world situations, select relevant information, and evaluate solutions based on practical considerations. As noted by Pratiwi et al. (2024), numeracy literacy integrates conceptual understanding, logical reasoning, and evaluative judgment, all of which are central to critical thinking. In this regard, the present findings extend prior research by illustrating how these processes manifest differently across SRL levels.

Despite its contributions, this study has several limitations. First, the qualitative findings were based on a limited number of interview participants, which restricts the generalizability of the identified thinking profiles. Second, SRL was measured using a self-report questionnaire, which may be subject to response bias. Third, the absence of inferential statistical analysis limits the strength of claims regarding the relationship between SRL and critical thinking. Many existing studies on self-regulated learning in mathematics rely on correlational designs and achievement measures, which

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underscores the need for exploratory studies that examine students' thinking processes in greater depth (El-Adl et al., 2020). Future research should involve larger samples, apply inferential or longitudinal designs, and consider additional variables such as learning motivation or cognitive style to further clarify the dynamics between SRL and critical thinking (Rahmawati & Alaydrus, 2021; Roslinda et al., 2022).

Nevertheless, the findings highlight important pedagogical implications. Supporting the development of students' critical thinking skills requires instructional strategies that explicitly foster self-regulation, such as encouraging goal setting, self-monitoring, and reflection during problem-solving activities. Experimental evidence suggests that structured instructional designs in mathematics can significantly enhance students' critical thinking skills, supporting the integration of reflective learning strategies in classroom practice (Arisoy et al., 2021). Learning approaches that emphasize problem-based and reflective learning may help create environments in which students' critical thinking and self-regulation develop in tandem, particularly in the context of numeracy literacy (Asmara & Septiana, 2024).

CONCLUSION

This study explored students' critical thinking skills in numeracy literacy problem solving across different levels of Self-Regulated Learning (SRL) using an exploratory mixed-methods approach. The findings indicate that students' critical thinking profiles vary according to SRL levels, with higher SRL associated with more reflective and evaluative thinking processes. Overall, the study highlights the relevance of self-regulation in understanding students' approaches to numeracy-based problem solving. Future research is encouraged to involve larger and more diverse samples and to employ inferential or longitudinal designs to further examine the relationship between SRL and critical thinking.

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INFORMED CONSENT

The authors have obtained informed consent from all participants.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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