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Metacognitive approach based on differences in self-regulated learning skills toward mathematical reflective thinking for primary school students

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ABSTRACT

Mathematical reflective thinking, a cornerstone of deep comprehension and effective problem-solving, frequently presents student challenges. This research explores the efficacy of a metacognitive strategy, examining its influence on primary school students' mathematical reflective thinking, particularly considering variations in Self-Regulated Learning (SRL) abilities. This research employed the quantitative methodology with a quasi-experimental design, incorporating pre-test and post-tests with non-randomized groups. Fifty fifth-grade students participated, and data was gathered through assessments and questionnaires. Statistical analysis, including univariate tests and independent samples t-tests, was conducted. The findings revealed a significant impact, with a p-value of 0.040 and an R-squared value of 0.855, indicating that 85.5% of the variance in reflective thinking could be attributed to the metacognitive approach. Notably, students demonstrating higher SRL levels exhibited a greater propensity to enhance their reflective thinking through metacognitive processes, such as planning, monitoring, and evaluation. Consequently, future research should explore reflective thinking with diverse learning interventions while still considering SRL differences and focusing on strengthening SRL generalization activities. This study implied that a metacognitive approach is a valuable pedagogical tool for educators and researchers aiming to foster mathematical reflective thinking while acknowledging and addressing individual cognitive variations, especially those related to SRL.

Pendekatan metakognitif berdasarkan perbedaan keterampilan self-regulated learning *terhadap pemikiran reflektif matematika pada siswa sekolah dasar*

Kata Kunci:

pendekatan metakognitif, siswa sekolah dasar, pemikiran reflektif, self-regulated learning

ABSTRAK

Pemikiran reflektif matematis, yang merupakan landasan pemahaman mendalam dan pemecahan masalah yang efektif, sering kali menimbulkan tantangan bagi siswa. Penelitian ini menyelidiki efektivitas strategi metakognitif, memeriksa pengaruhnya terhadap pemikiran reflektif matematis siswa sekolah dasar, khususnya dengan mempertimbangkan variasi kemampuan Self-Regulated Learning (SRL). Menggunakan metodologi kuantitatif, penelitian ini menggunakan desain kuasi-eksperimental, yang menggabungkan pra-tes dan pasca-tes dengan kelompok non-acak. Lima puluh siswa kelas lima berpartisipasi, *dan data dikumpulkan melalui penilaian dan kuesioner. Analisis statistik, termasuk uji univariat dan uji t sampel independen, dilakukan. Temuan mengungkapkan dampak yang signifikan, dengan nilai p 0,040 dan nilai R-kuadrat 0,855, yang menunjukkan bahwa 85,5% varians dalam pemikiran reflektif dapat dikaitkan dengan pendekatan metakognitif. Khususnya, siswa yang menunjukkan tingkat SRL yang lebih tinggi menunjukkan kecenderungan yang lebih besar untuk meningkatkan pemikiran reflektif mereka melalui proses metakognitif, seperti perencanaan, pemantauan, dan evaluasi. Oleh karena itu, penelitian di masa depan harus mengeksplorasi pemikiran reflektif dengan intervensi pembelajaran yang beragam, sambil tetap mempertimbangkan perbedaan SRL, dan fokus pada penguatan kegiatan generalisasi SRL. Penelitian ini berimplikasi bahwa bahwa pendekatan metakognitif berfungsi sebagai alat pedagogis yang berharga bagi pendidik dan peneliti yang bertujuan untuk menumbuhkan pemikiran reflektif matematis, sambil mengakui dan mengatasi variasi kognitif individu, terutama yang berkaitan dengan SRL*

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Contribution to the literature

This research contributes to:

- Providing the impact of the metacognitive approach based on different SRL skills toward mathematical reflective thinking for primary students.
- Providing a new understanding of how the metacognitive approach can be applied to primary students with different SRL skill levels.
- The findings show that students with higher levels of SRL tend to be more able to enhance reflective thinking through metacognitive approaches such as planning, monitoring, and evaluation.

1. INTRODUCTION

Reflective thinking belongs to the category of higher-order thinking skills [1]. Mathematical reflective thinking is essential to developing students' understanding and problem-solving skills [2]. Students are allowed to reflect on their learning process independently [3]. For primary school students, reflective thinking is needed to systematically organize ideas that can be connected between the before and after stages of solving a problem [4]. Someone with reflective thinking relies on two main aspects: attitude and knowledge. Attitude includes sincerity, openness, honesty, responsibility, and readiness. The knowledge aspect can be seen as a person's ability to connect between concepts [5].

According to Dewey, reflective thinking is an active, persistent, and careful process of considering a belief or form of knowledge with the basis supporting it and its conclusions. For primary school students, reflective thinking has a vital role in learning. With reflective thinking, students will gain knowledge through the learning instruction. Primary school students can observe the learning course and use it to encourage their thinking skills in finding strategies to be used in problem-solving [6]. Students can enhance their higher-order thinking skills by connecting new knowledge with their prior understanding, thinking in abstract and concrete contexts, implementing specific strategies to answer a question, and understanding their thinking processes and learning strategies [7]. Reflective thinking gives one the confidence to solve problems easily [5]. Thus, it can be used as a benchmark to determine the effectiveness of achieving learning objectives [8].

Indonesian students' reflective thinking is poor [9], evidenced by the low achievement in the PISA (Program for International Student Assessment) study. In the 2018 PISA study, Indonesian students ranked 72 out of 78 countries with an average mathematical ability score of 379. One of the factors contributing to Indonesia's low PISA results is the lack of practice among students in solving contextual problems that require reasoning, argumentation, and creativity. These problems demand a deep understanding of their meaning before students can effectively solve them [10]. Reflective thinking involves solving problems, establishing connections between ideas, and choosing the most appropriate strategy [11]. It requires responding to existing problems by utilizing previously acquired knowledge, experience, reasoning, and understanding as a basis for thinking and acting [12]. These abilities are closely related to students' mathematical reflective thinking. Therefore, it is necessary to enhance reflective thinking for primary school students.

For primary school students, reflective thinking is vital in helping them evaluate their experiences, learn from errors, and connect new knowledge with existing understanding [6]. Reflective thinking will be formed by responding to problems in learning whose solutions cannot be solved directly so that educators can observe students' skills in connecting current knowledge with previous knowledge to be processed into new knowledge [13]. However, many primary school students face challenges in enhancing reflective thinking. Therefore, previous researchers enhanced reflective thinking indicators based on certain aspects. The aspects contain three indicators: students must understand the information, understand the problem question, and monitor whether the solution is correct or not to solve a problem [1]. These indicators impact students who only focus on answering a problem without going through the planning, monitoring, and evaluation process.

Based on the existing problems, the lack of students' mathematical reflective thinking shows the lack of success of the learning applied by the teacher so far. One solution to overcome the existing problems is to enhance the learning process [14]. The right effort to make in learning is to use the right learning approach, namely the metacognitive approach [15]. In the learning process, students are allowed to react, compare, and contemplate the process of cognitive activities during the learning process [4].

In addition to using a metacognitive approach, learning mathematics requires SRL to manage the learning process effectively. SRL can be defined as self-management. This self-management is intended to be the human ability to organize and carry out activities in the learning process [16]. SRL is an essential aspect of the learning process, so it needs to be mastered by students [17]. There are three phases in forming SRL: forethought and planning, performance monitoring, and reflections on performance [18].

Other researchers have shown that the metacognitive approach effectively enhances reflective thinking, but no one has examined it with different SRL skills. Some previous studies have shown that the metacognitive approach is effective in enhancing problem-solving skills based on thinking style [19], problem-solving based on mathematical disposition [20], mathematical reasoning ability of primary school students [4], mathematical problem-solving [21], mathematical anxiety [22], and intelligence quotient [23]. However, students' mathematical reflective thinking can be enhanced by using other learning models that are more effective than the learning models studied [2].

The studies related to the metacognitive approach, SRL skills, and mathematical reflective thinking are conducted separately and can be grouped into three themes. First, studies on the metacognitive approach related to mathematical reflective thinking, but not

SRL skills. These include studies towards initial mathematical ability [24], Appy Pie learning media [25], animation videos [26], and problem-based learning [27]. Second, studies on SRL skills related to mathematical reflective thinking are unrelated to the metacognitive approach. This includes studies on problem-based learning [28], SRL as learning [29], and the network analytics approach [30]. Third, studies focusing on mathematical reflective thinking are unrelated to the metacognitive approach and SRL skills. These include studies towards reflective, collaborative learning [31], role-playing learning model [32], SSCS learning model [33], and inquiry learning model [34]. Therefore, there have been no studies on the metacognitive approach, SRL skills, and mathematical reflective thinking conducted simultaneously and specifically involving primary school students. Thus, this study's novelty lies in examining the implementation of the metacognitive approach by considering the differences in SRL skills expected to enhance mathematical reflective thinking for primary school students.

This study aims to analyze the impact of students' metacognitive approach based on differences in SRL skills toward mathematical reflective thinking for primary school students. This analysis is expected to enhance students' mathematical reflective thinking by implementing a metacognitive approach by looking at differences in students' SRL skills. The need for a curriculum that emphasizes the development of higher-order thinking skills makes the metacognitive approach an effective strategy for learning mathematics in primary schools because it helps students monitor, evaluate, and reflect on their thinking processes. In addition, SRL skills affect the effectiveness of the metacognitive approach [35]. This study is critical to enhance the quality of learning and develop students' mathematical reflective thinking. The results of this study are expected to be the basis for designing learning interventions by implementing a metacognitive approach tailored to the needs of students based on the level of SRL skills.

2. METHOD

The research method was a quantitative study with a quasi-experimental non-randomized pre-test and post-test design. The design involved two classes, namely experimental and control. The random sampling technique was used to select the experimental and control classes [36]. After receiving ethics approval, the research was conducted. The experimental class applied a metacognitive approach with SRL difference, while the control class applied conventional direct learning with SRL difference. The study participants were fifth-grade students. The total participants in the sample consisted of 50 students, namely 23 students in the experimental class and 27 in the control class. After receiving consent from parents and students, the research was conducted. Participants were determined using a random sampling technique. The researcher used a random sampling technique to select the experimental and control classes. The research design of the experimental and control class was based on Creswell & Creswell [36].

Experimental	O_1	X_1	P_1	O_3
Control	O_2	X_2	P_2	O_4

Description:
O_1 dan O_2 : Pre-test
O_3 dan O_4 : Post-test
X_1 : Metacognitive approach with SRL differences
X_2 : Conventional learning with SRL differences
P_1 dan P_2 : Reflective thinking of experimental and control classes

This study applies the three syntaxes of the metacognitive approach, according to Fajri and Amir [22]. In the planning stage, students understood the problem, considered representations, recalled prerequisite materials to assist in solving the task, and identified the solution strategy to be used. During the monitoring stage, the teacher guided students in controlling the implementation of problem-solving activities. In the evaluation stage, students identified improvement strategies in case of errors, assessed the results obtained, and evaluated the methods or strategies used for problem-solving. The metacognitive approach was implemented in lessons on the least common multiple and greatest common factors.

The study utilized written tests and questionnaires as research instruments. The test measured students' mathematical reflective thinking, while the questionnaire assessed their self-regulated learning (SRL) skills. The written test consisted of four problems designed to evaluate students' reflective thinking, developed based on the indicators proposed by Hartati *et al.* [2]: reacting, comparing, and contemplating. The reflective thinking indicators are presented in Table 1. The questionnaire was developed according to the SRL dimensions outlined by Zimmerman and Schunk [18], measuring students' mathematical reflective thinking regarding forethought, performance, and self-reflection. Additionally, the questionnaire examined variations in students' SRL. The questionnaire framework is presented in Table 2.

Table 1. Indicators of Reflective Thinking

Phase	Indicator
Reacting	Identifying the information in the problem.
	Identifying the purpose of the problem.
	Connecting the information and the problem in question.
Comparing	Relating similar problems to the problem at hand.
	Relating similar problem solutions to the problem at hand.
Contemplating	Performing problem-solving.
	Concluding the problem.
	Evaluating the problem.

Tabel 2. SRL Questionnaire Grid

No	Dimensions	Indicator	Number		Total
			Positive	Negative	
1.	Forethought	Self-analysis task	1	17	2
		Goal setting	13	19	2
		Strategic planning	16	31	2
		Self-motivation belief	2	23	2
		Self-efficacy	30	32	2
		Outcome expectation	3	22	2
		Internal approach	4	27	2
		Goal orientation	21	29	2
			Number of cognitive dimension items		16
2.	Performance	Self-control	6	9	2
		Self-instruction	33	34	2
		Imaginary	10	26	2
		Attention focusing	5	28	2
		Task strategy	8	14	2
		Self-observation	11	25	2
		Self-recording	35	36	2
		Self eksperimentation	7	24	2
			Number of performance dimension items		16
3.	Self Reflection	Self-judgement	12	20	2
		Self-evaluation	37	38	2
		Causal attribution	39	40	2

	Self reaction	15	18	2
	Self-satisfaction/affect	41	42	2
	Adaptive defensive	43	44	2
			Number of self-reflection dimension items	12
			Total items of the SRL scale	44

The data analysis involved a univariate test and a two-independent-sample t-test. The univariate test was used to analyze a single variable in the data. At the same time, the independent sample t-test compared the average test results between two different classes or examined whether there was a significant difference between two groups of individuals who received different treatments. Additionally, the questionnaire test categorized respondents or study objects into high, medium, and low categories based on the SRL [37]. The analysis was conducted using IBM SPSS Statistics 26, applying the normalized gain formula (n-gain). The research flow is illustrated in Figure 1.

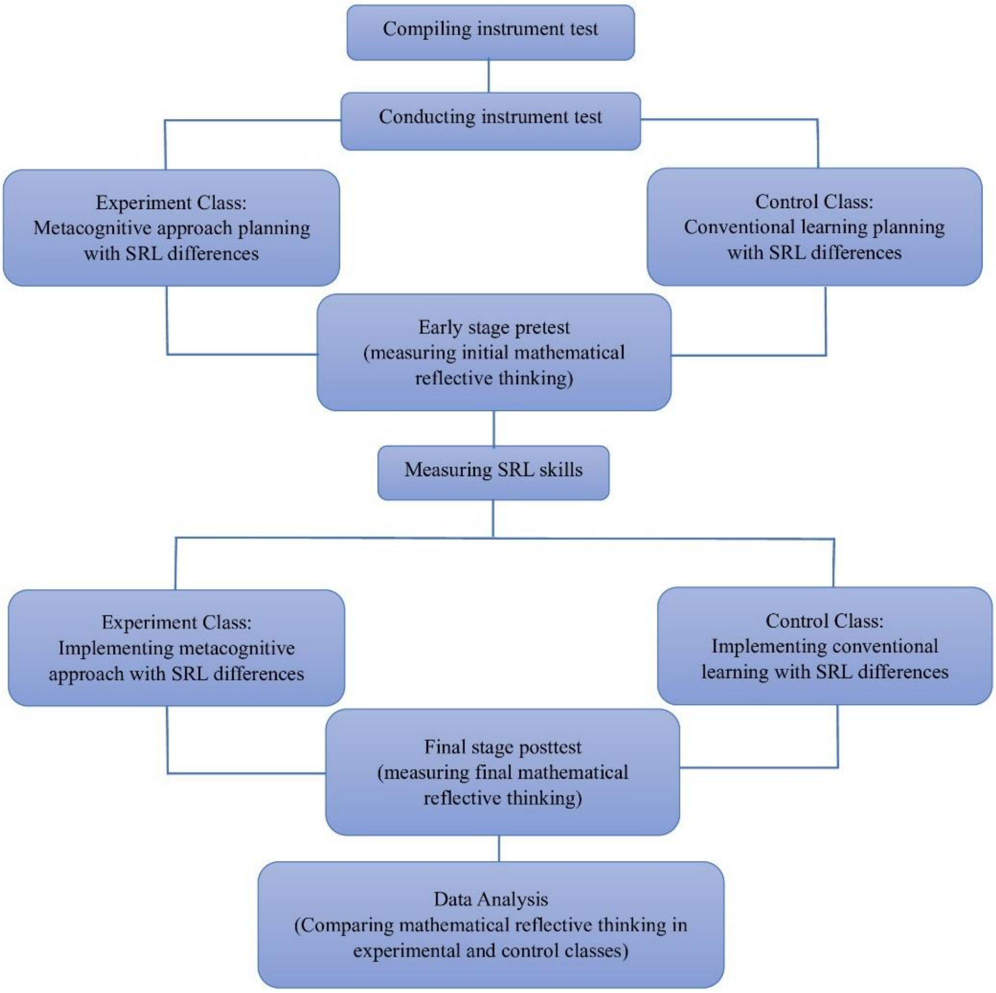


Figure 1. Research Flow

3. RESULTS AND DISCUSSION

The implementation of experimental and control classes was analyzed in the data analysis. In the experimental class, the researcher applied the treatment by implementing a metacognitive approach with SRL differences and implemented conventional learning with SRL differences in the control class. Before treating both classes, the researcher tested the instrument and measured the SRL skills. Next, the researchers conducted a post-test to analyze the difference between mathematical reflective thinking in experimental and control classes.

3.1 The Implementation of Metacognitive Approach with SRL Differences

Implementing a metacognitive approach with SRL differences is based on the syntax and activities in terms of planning, monitoring, and evaluation in the experimental class. Table 3 shows the syntax and activities performed.

Table 3. Syntax and Activities of Metacognitive Approach with SRL Differences

Syntax	Activities
Planning	The teacher prepares students for learning. The teacher presents the learning objectives. The teacher gives contextual problems to students with the help of a metacognitive approach. The teacher forms groups and administers a pre-test. Students fill out the SLR questionnaire. Students identify the information provided and the information needed for problem-solving. Students determine the approach or method used for problem-solving with SRL differences.
Monitoring	Students start working on the solution according to the strategy that has been designed. The teacher checks whether the stage the students perform is by the initial planning. Students discuss with friends or teachers to ensure that the understanding and stages taken are correct.
Evaluation	Students check to make sure there are no errors. The teacher invites students to evaluate the strategies' effectiveness and identify possible enhancements or alternative strategies. The teacher gives a conclusion.

3.2 The Implementation of Conventional Learning with SRL Differences

In the control class, conventional learning with SRL differences was implemented. Conventional learning was done by equalizing the learning applied in the research site. The teacher delivered the learning material without the intervention of a metacognitive approach but with attention to SRL differences. The learning process followed the regular classroom routines. After implementing learning in two different classes, the researchers conducted a post-test to determine the enhancement of mathematical reflective thinking. Then, data analysis was conducted.

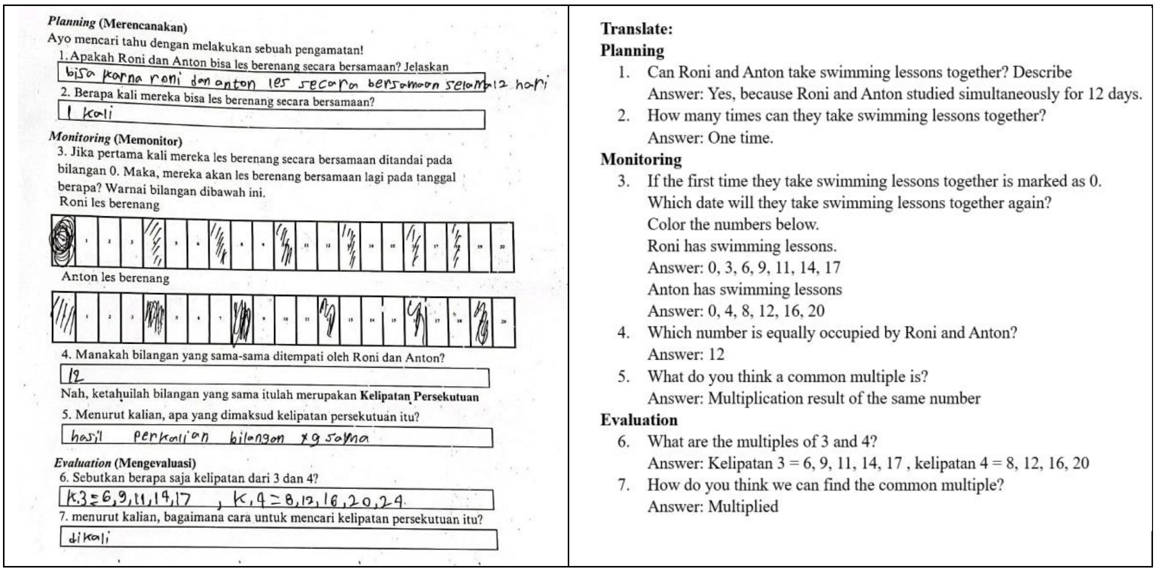
3.3 The Comparison between Metacognitive Approach and Conventional Learning

This study revealed differences in treatment between the experimental and control classes. The experimental class received treatment through a metacognitive approach, where students were grouped based on SRL differences to encourage reflective thinking. During the implementation, students discussed planning, monitoring, and evaluation. This grouping strategy was aimed at fostering deeper individual awareness of learning processes. Such reflective engagement was expected to improve students' ability to self-regulate and solve problems effectively. In contrast, the control class underwent conventional learning without the metacognitive approach, following the usual learning process without special intervention. The differences in treatment between the two classes are illustrated in Figure 2. Figures 2.a and 2.b illustrate the differences in activities between the experimental and control classes. Figure 2. depicts the experimental class, which implemented the metacognitive approach with SRL differences. In this approach, students engaged in discussions during the planning, monitoring, and evaluation stages. In contrast, Figure 2.b showed that the control class followed conventional learning, where students did not participate in discussions as in the experimental class.

(a) (b)

Figure 2. Sampling Activity: **(**a) Metacognitive Approach and (b) Conventional Learning

During planning, students analyzed problems by identifying available information and determining the appropriate steps or solution strategies. In the monitoring stage, they regulated the problem-solving process. In the evaluation stage, students assessed the effectiveness of the methods or strategies used in solving the problems. Figure 3 presents the activities reflecting the implementation of planning, monitoring, and evaluation in problem-solving.



***Planning* (Merencanakan)**
Ayo mencari tahu dengan melakukan sebuah pengamatan!
1. Apakah Roni dan Anton bisa les berenang secara bersamaan? Jelaskan
bisa karna roni dan anton les secara bersamaan selama 12 hari
2. Berapa kali mereka bisa les berenang secara bersamaan?
1 kali

***Monitoring* (Memonitor)**
3. Jika pertama kali mereka les berenang secara bersamaan ditandai pada bilangan 0. Maka, mereka akan les berenang bersamaan lagi pada tanggal berapa? Warnai bilangan dibawah ini.
Roni les berenang
Anton les berenang
4. Manakah bilangan yang sama-sama ditempati oleh Roni dan Anton?
12
Nah, ketahuilah bilangan yang sama itulah merupakan **Kelipatan Persekutuan**
5. Menurut kalian, apa yang dimaksud kelipatan persekutuan itu?
hasil perkalian bilangan yg sama

***Evaluation* (Mengevaluasi)**
6. Sebutkan berapa saja kelipatan dari 3 dan 4?
K.3 = 6,9,11,14,17 , K.4 = 8,12,16,20,24
7. menurut kalian, bagaimana cara untuk mencari kelipatan persekutuan itu?
dikali

Translate:
Planning
1. Can Roni and Anton take swimming lessons together? Describe
Answer: Yes, because Roni and Anton studied simultaneously for 12 days.
2. How many times can they take swimming lessons together?
Answer: One time.

Monitoring
3. If the first time they take swimming lessons together is marked as 0. Which date will they take swimming lessons together again? Color the numbers below.
Roni has swimming lessons.
Answer: 0, 3, 6, 9, 11, 14, 17
Anton has swimming lessons
Answer: 0, 4, 8, 12, 16, 20
4. Which number is equally occupied by Roni and Anton?
Answer: 12
5. What do you think a common multiple is?
Answer: Multiplication result of the same number

Evaluation
6. What are the multiples of 3 and 4?
Answer: Kelipatan 3 = 6, 9, 11, 14, 17 , kelipatan 4 = 8, 12, 16, 20
7. How do you think we can find the common multiple?
Answer: Multiplied

Figure 3. Results of Planning, Monitoring, and Evaluation Activities

3.4 Data Analysis Results

Students' n-Gain mathematical reflective thinking data were analyzed and presented through several stages: descriptive statistics, normality test, univariate test, and t-test. The initial stage was descriptive statistical analysis, providing an overview of the data, including the mean and standard deviation values. This initial analysis serves as the foundation for further statistical testing and interpretation. Table 4 explains the mean and standard deviation of the n-Gain mathematical reflective thinking data of students in the experimental and control classes.

Table 4. Descriptive Statistic of the Study Data (n-Gain)

Class	Mean	St. Deviation	N
Experimental	79.98	21.164	23
Control	56.73	34.642	27

Table 4 showed that the mean n-Gain of the experimental class was 79.98 (SD = 21.164), while that of the control class was 56.73 (SD = 34.642). This indicated that the mean of the experimental class was higher than that of the control class. The standard deviation of the experimental class was relatively smaller, suggesting that the data distribution around the mean in the experimental class was more concentrated than in the control class. Table 5 describes students' reflective thinking based on SRL differences, categorized into high, medium, and low levels in the experimental and control classes.

Table 5. Mathematical Reflective Thinking Based on SRL Differences and n-Gain Levels

Class	Number of Students	n-Gain Level	Total of Students
Experimental	23	High	18
		Medium	5
		Low	0
Control	27	High	9
		Medium	13
		Low	5

Table 5 showed that students' mathematical reflective thinking was divided into three levels based on SRL differences in the experimental class. In the experimental class, 18 students with high SRL and 5 students with medium SRL were found, while no students with low SRL were found. This suggests that the intervention given in the experimental class may have contributed to the absence of students with low SRL.Meanwhile, in the control class, students' mathematical reflective thinking was divided into three levels: nine students with high SRL, 13 with medium SRL, and 5 with low SRL. This difference indicated that in the experimental class, no students exhibited mathematical reflective thinking at the low SRL level, unlike the control class, which included students from all SRL levels.

3.4.1 Normality Test

The normality of the experimental and control class data, a prerequisite for the t-test, was determined as shown in Table 6. The hypothesis formulation was as follows:
H0 : Data is normally distributed
H1 : Data is not normally distributed

Table 6. The Result of the Normality Test of Experimental and Control Classes

Group	Chi-Square	Sig.	Conclusion	Information
Reflective thinking	11.308	0.004	H_0 is rejected	Data is normally distributed.

Table 6 showed that the n-gain score data for the experimental and control groups were normally distributed (p = 0.059). If the p-value was greater than 0.05, the n-gain data were considered normally distributed. Conversely, if the p-value was less than 0.05, the n-gain data were not normally distributed. This result indicated that parametric tests could be appropriately applied to the data. Furthermore, a comparative test was conducted to examine differences in enhancing reflective thinking based on variations in SRL between the experimental and control classes.

2.4.2 Univariate Test

Univariate tests were used to examine the homogeneity of data variance and the mean improvement in students' mathematical reflective thinking ability. Additionally, they assessed whether differences in SRL influenced students' mathematical reflective thinking in the experimental and control classes.

Table 7. Descriptive Statistics and Levene Test for Experimental and Control Classes

Reflective Thinking	Mean	N	Levene test	F-count	Sig.
Experiment	95.65	23		1.811	0.185
Control	69.04	27			

Table 7 indicated that the variance between data groups was homogeneous (F=1.811, p=0.185). The table also presented students' mean mathematical reflective thinking scores in the experimental class (M=96.65) and the control class (M=69.04). The mean score of students in the experimental class was higher than that of the control class. The detailed univariate test results are provided in Table 8.

Table 8. Univariate Test Results

Source	Sum of Square	df	Mean Square	F	Sig.
Corrected Model	10.620a	2	.109	3.609	.040
	89.816	1	7.558	249.466	.000
Reflective thinking	10.620	2	.109	3.609	.040
Error	1.800	28	.030		
Total	131.000	31			
Corrected Total	12.420	30			
R Squared = .855 (Adjusted R Squared)					

Table 8 illustrates the impact of SRL on students' mathematical reflective thinking. The data indicated that SRL influenced students' mathematical reflective thinking (p=0.040, R^2=0.855 or 85.5%). This suggested that differences in SRL in the experimental class accounted for 85.5% of the variation in reflective thinking (F=3.609, p=0.040). This difference resulted from the treatment using a metacognitive approach, which enabled students to recognize their ability to select the most effective solution method. Metacognitive awareness plays a crucial role in problem-solving, encompassing knowledge of appropriate strategies, their application, and their implementation. Thus, implementing a metacognitive approach based on SRL differences enhanced students' mathematical reflective thinking.

3.4.3 Mean Difference Test Results

The t-test was conducted to determine whether there was a difference in enhancing reflective thinking between groups that used the metacognitive approach (experimental class) and those that received conventional learning (control class). The results are presented in Table 9.

Table 9. Two-Sample T-test Results

T-value	df	Sig. (2-tailed)	H_0
3.812	48	.000	Rejected
3.898	47.380	.000	Rejected

The results in Table 9 indicated a significant difference in enhancing reflective thinking between students who used the metacognitive approach (t=3.812, p=0.000) and those who underwent conventional learning (t=3.898, p=0.000). This highlighted the varying impact of implementing the metacognitive approach with SRL compared to conventional learning on mathematical reflective thinking. In other words, implementing a metacognitive approach with SRL in the experimental class significantly impacted mathematical reflective thinking, whereas conventional learning with SRL did not produce a significant effect.

The analysis of the study results revealed that students' reflective thinking in the experimental class improved after implementing the metacognitive approach. This finding confirmed that the metacognitive approach significantly influenced students' reflective thinking, aligning with previous research on the intervention of metacognitive strategies in fostering reflective thinking [38]–[40]. Experts explained that the metacognitive approach promoted student independence in the learning process [41], [42]. Reflective thinking emphasizes active learning, encouraging students to engage in the process and connect new concepts with prior knowledge [43]. Additionally, SRL skills were found to influence the effectiveness of the metacognitive approach [35], [44].

The results supported the first hypothesis, which proposed a relationship between the metacognitive approach and mathematical reflective thinking. This occurred because the metacognitive approach enabled students to actively plan, monitor, and evaluate their thinking processes during learning. Statistical analysis demonstrated that applying a metacognitive approach enhanced reflective thinking positively. These findings aligned with previous studies [15], [25], concluding that the metacognitive approach improved mathematical reflective thinking. Implementing the metacognitive approach elicited a favourable response, as the difference in instructional treatment between the experimental and control classes led to distinct variations in students' mathematical reflective thinking. In the experimental class, where the metacognitive approach was applied, students could regulate their thought processes, allowing for more structured reflective thinking when solving problems. Conversely, in the control class, which did not employ the metacognitive approach, students' reflective thinking remained limited in problem-solving situations.

The results supported the second hypothesis, which suggested a relationship between SRL skills and mathematical reflective thinking. This was evident as SRL significantly influenced students' ability to engage in mathematical reflective thinking. Statistical analysis further confirmed that SRL contributed positively to enhancing reflective thinking. This finding aligned with previous research demonstrating that SRL-based learning strengthened mathematics learning outcomes [45]. However, students with low SRL encountered difficulties in problem-solving, reinforcing the notion that SRL played a critical role in students' mathematical reflective thinking. Those with high SRL exhibited greater problem-solving capabilities than those with lower SRL. Similar findings were reported in previous studies [28], [46], which aimed to enhance SRL and reflective thinking. The study results indicated that students’ SRL levels influenced their mathematical reflective thinking. The distinction in instructional treatment between the experimental and control classes further explained this difference. In the experimental class, no students exhibited low SRL levels in mathematical reflective thinking, whereas the control class included students across all SRL levels: high, medium, and low.

The study has not yet specifically assessed the effect of the metacognitive approach on mathematical reflective thinking concerning different levels of SRL (high, medium, and low) [47]. While it explains that the metacognitive approach contributes to SRL [48], it does not explicitly analyze SRL levels. Other studies suggest integrating SRL with a metacognitive approach can enhance mathematical reflective thinking. Further research is needed to explore how the metacognitive approach can be optimized to support reflective thinking across different SRL levels.

These findings have several implications. First, teachers must design engaging learning activities that effectively integrate the metacognitive approach, requiring time and effort. Creating a supportive learning environment, providing positive feedback, and fostering an enjoyable, less intimidating mathematics experience are essential. Second, since students have varying cognitive abilities, instructional strategies should be studentcentred and aligned with the curriculum. The metacognitive approach aims to enhance students' ability to recognize, understand, and regulate their thought processes independently. Third, providing opportunities for students to develop metacognitive skills is crucial. Relevant questions foster reflective thinking. However, implementing this approach requires more time than conventional methods, as teachers must provide detailed guidance at each stage. Developing metacognitive abilities enables students to reflect on their thinking, evaluate problem-solving strategies, and build confidence in learning.

Additionally, SRL enhances mathematical reflective thinking among primary school students. By applying SRL skills, students become more active in managing their learning—from planning and monitoring to evaluating their mathematical understanding. This process encourages them to reflect on problem-solving steps, identify mistakes, and assess the effectiveness of their strategies. As a result, SRL-based learning helps students develop deeper conceptual understanding and reflective thinking skills essential for solving problems.

This study has some limitations. It does not analyze the metacognitive approach's effects on mathematical reflective thinking at each SRL level (high, medium, and low). Further research should examine how metacognitive strategies influence students with different SRL abilities. The sample size was also small: fifth-grade students from a single school. Future studies should involve a more diverse group of primary school students across various schools while considering other factors influencing the study's outcomes.

4. CONCLUSION

The study results indicate that implementing the metacognitive approach significantly influences reflective thinking, depending on students' levels of SRL. Reflective thinking improves before and after applying the metacognitive approach, particularly among students with high SRL, who can better enhance their reflective thinking through planning, monitoring, and evaluation strategies. In contrast, students with low SRL struggle to develop reflective thinking.

By employing a metacognitive approach, students gain a deeper understanding of their thought processes, which enhances their ability to analyze, evaluate, and solve problems. Future research should continue exploring reflective thinking while considering SRL differences, incorporating alternative learning interventions, and reinforcing the generalization of SRL to make it more meaningful and constructive. This study suggests that the metacognitive approach can be an effective learning strategy for teachers and researchers aiming to enhance mathematical reflective thinking while accounting for cognitive differences, particularly in SRL.

AUTHOR CONTRIBUTION STATEMENT

NFC contributed to teaching using a metacognitive approach and SRL differences to enhance mathematical reflective thinking for primary school students. MFA and MDKW contributed to supporting instruments. NFC conducted calculations, data analysis, and hypothesis testing.

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