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Research Article

Evaluating metacognitive strategies and self-regulated learning to predict primary school students' self-efficacy and problem-solving skills in science learning

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The use of metacognitive and self-regulated strategies is a potential predictor of problem-solving skills and self-efficacy. However, this potential needs to be seen at the level of knowledge and experience of various attributes and forms of activity. This research aims to see the interaction effect of using metacognitive and self-regulated strategies on problem-solving skills and self-efficacy in primary school students. This research is quantitative in the form of a factorial design with a 2x2 design. A total of 100 primary school students were the subjects of data mining through tests and questionnaires. The results of this study show that both metacognitive and self-regulated strategies separately positively influence problem-solving skills and self-efficacy. However, when combined with the analysis, it shows that there is no interaction pattern of metacognitive and self-regulated strategies in each of the problem-solving and self-efficacy variables. The use of metacognitive strategies and also self-regulation has a different impact on problem-solving which shows that students tend to be resistant to these attributes in learning. This is thought to be caused by the knowledge style and experience attributes possessed by primary school students. Apart from that, learning styles and science materials, which are mostly in the form of concepts, also have allusions, so the combination of the two needs to be analyzed more deeply. Future teachers and researchers can use this research as a basis for testing the potential interaction of many attributes and skills at certain cognitive levels.

Keywords: Metacognitive strategy; Self-regulated learning; Problem-solving; Self-efficacy; Science learning

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1. Introduction

Science learning aims to systematically explore nature, fostering knowledge, curiosity, and understanding of the relationship between science, environment, technology, and society (Anggoro et al., 2022). In primary school, science subjects cover four groups: living creatures, objects, energy, and the universe. The subject matter is complex, focusing on living creatures, materials, energy, and the earth and universe (Margunayasa et al., 2019; Nurkolis, 2021). Active learning is essential for students to gain maximum effects on understanding materials and the learning process. Science learning goals require students to solve problems using science concepts.

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Primary school students' problem-solving skills are closely linked to their self-efficacy, which is related to achieving academic goals independently and confidently showing performance (Ariff et al., 2021; Regier & Savic, 2020; Shkëmbi & Treska, 2023). Self-efficacy predicts subsequent performance better than past behavior, with dimensions including magnitude, strength, and generality. Both problem-solving skills and self-efficacy are commonly investigated in science learning (Bal & Or, 2022; Rasyidina et al., 2023).

In primary school, an active learning requires appropriate strategies that involve attitude and active thinking in science learning. Metacognitive strategies focus on deeper processing, planning, monitoring, and organizing cognition (Divrik et al., 2020). It could be one of the alternative strategies helping students to understand how concepts are built from regularities perceived in objects or events by linguistic or symbolic labels and offer practice in building valuable claims. To address students' self-efficacy, teachers should also determine correlated attributive aspects since the efficacy is aggregated also from another attributive determiner. Self-regulated learning is one of the potential attibutive determiners of successful active learning as well as a positive attitude during learning. The previous studies examined the pairs of these factors and acknowledged positive correlations. A lack of studies investigated these factors comprehensively and specifically in primary school students. It is important to investigate the use of metacognitive strategy and self-regulated learning as moderators toward the students' problem-solving skills and self-efficacy as learning outcomes and to determine the interaction of potential determinant factors of successful science learning. The study will contribute to the field of facilitating proper science learning and extend factors to the improving higher-order thinking performance of primary schools.

Based on the above-stated aim, the following are the research objectives of the present study;

RQ1) To what extent is the effect of metacognitive strategy on primary school students' self-efficacy in science learning?

RQ2) To what extent is the effect of metacognitive strategy on primary school students' problem-solving in science learning?

RQ3) To what extent is the effect of self-regulation on primary school students' self-efficacy in science learning?

RQ4) To what extent is the effect of self-regulation on primary school students' problem-solving in science learning?

RQ5) To what extent is the effect of metacognitive strategy and self-regulation simultaneously on primary school students' self-efficacy in science learning?

RQ6) To what extent is the effect of metacognitive strategy and self-regulation simultaneously on primary school students' problem-solving ability in science learning?

2. Literature Review

2.1. Metacognitive Strategy

Metacognition refers to a person's ability to think about how one thinks and learns (Boyle et al., 2016). Metacognitive strategies are deeper processing strategies including planning, monitoring, and organizing that assist students in controlling and regulating cognition (Divrik et al., 2020). Metacognitive strategy in science learning leads students to promote meaningful learning and continue to maintain attention. Akyol et al. (2010) found that the use of cognitive and metacognitive strategies was related to scientific achievements even though need to be related to other classroom climate variables that may hinder student functioning. Metacognition is a complex process that involves the knowledge of cognition and the regulation of cognition (Shraw, 1998). Knowledge of cognition is a set of skills and knowledge, divided into declarative, operational, and situational knowledge. Regulation of cognition is a set of strategic activities, including planning, monitoring, controlling, and evaluation (Öztürk, 2021). Planning involves setting a goal, while regulation involves controlling, monitoring, and making predictions. Controlling involves checking for mistakes and ensuring the process is successful. Both components are essential for effective metacognition and personal growth (Özturk et al., 2024).

Metacognition is a learning tool used in various approaches, such as metacognitive training, which focuses on questioning and strategies (Ay & Bulut, 2017). Some of these methods include problem-solving approaches, good strategy user models, cognitive awareness-based problem-solving methods, etc. One of the metacognitive strategies that students use to monitor their understanding during learning is self-questioning. Self-questioning is considered a metacognitive strategy because it functions as self-testing and helps students constantly check on their understanding during learning (Perry et al., 2019). Self-questioning could enhance students' comprehension through three theories: schema theory, metacognitive theory, and active processing theory (Alutaybi & Alsowat, 2020). Schema theory activates students' background knowledge through self-questioning, which associates incoming information with existing knowledge for successful listening comprehension. Self-questioning helps students monitor their comprehension by identifying important information and regulating their listening process. Active processing theory suggests that self-questioning increases comprehension and generates higher-level questions, allowing students to actively engage with the text content. Overall, self-questioning is a valuable tool for effective teaching and learning. Self-questioning is a dominant metacognitive strategy used in primary school, empowering students to become active learners, increase understanding, and improve academic grades (Joseph et al., 2016). Especially in science learning, self-questioning helps form concrete to abstract concepts connections and prior knowledge, making it a valuable tool for students (Zohar & Barzilai, 2013).

2.2. Self-Regulated Learning

Self-regulated learning is strongly related to metacognitive theory. Metacognition is a person's knowledge respects self-constructed understanding under one's own control and monitoring. Self-regulated learning is a constructivist learning theory that adheres to a vision of the ability to self-manage the learning activity. Self-regulatory learners can manage and solve complex learning problems. Moreover, a self-regulated learner is motivated by internal learning itself, rather than compliments or other external motivators. Self-regulated learning [SRL] refers to student control of the learning process. Zimmerman (2000a) defines SRL as self-generated and cyclically planned thoughts, feelings, and actions adapted to the achievement of personal goals. Pintrich (2004) defines four SRL assumptions: (a) students are active participants in learning, constructing meaning from the information available in the environment combined with what they already know; (b) students can control and regulate aspects of their thinking, motivation and behavior and in some cases, the environment; (c) learners compare progress toward a goal against some criterion, and this comparison informs them about the status of progress toward the goal and (d) self-regulatory mechanisms mediate between the person, the context and achievement. Self-regulatory students set goals and then choose strategies and monitor their progress toward achieving goals and then evaluate the effectiveness of their strategies. They effectively adapt to new conditions, adjust goals, and make tactical choices to work toward the realization of those goals in changing learning conditions (Muis et al., 2016).

Effective methods to train self-regulation involve exposing students to social models, teaching them to use learning strategies, providing them with practice and corrective feedback, and accompanying them to evaluate progress on their learning goals (Perry et al., 2018). Internalizing the various social influences in the learning environment will aggregate the influences on the students' self-regulation process. The most effective applications are combining self-regulation processes with academic learning instruction (Linden et al., 2021). During the learning process, self-regulation plays an integral role in the development of skills and awareness of improvements in their academic performance (Hypothesis [H] 4), and experience an increased sense of personal efficacy. Steps for learning with self-regulation in the classroom included self-evaluation and monitoring, goal setting and strategic planning, strategy monitoring, and outcome monitoring.

Zimmerman explains that self-regulation is influenced by motivation, self-disclosure (self-awareness), and environmental influences both social and physical (Shi et al., 2024). Self-regulated subprocess includes self-monitoring to better differentiate between their behavioral events and their relationship to environmental consequences; self-instruction and self-reinforcement to provide discriminative stimuli and direct consequences in chains of behavior that ultimately lead to reinforcement of environmental consequences (Ök & Sarıtaş, 2022).

2.3. Metacognitive Strategy and Self-Regulation Potential Combination

Metacognitive processes are essential to achieve effective cognitive control in learning. Similarly, self-regulation, although often an indirect factor, determines learning achievement. Both are factors that influence student success in various types of achievement. The combination of the two can be brought together in an aptitude-treatment interaction (ATI) framework (Yeh, 2012). This paradigm posits that individuals vary in their readiness to benefit from a specific intervention, and individuals may modify their circumstances to align with their own attributes. ATI provides a framework for viewing aptitudes as an individual's readiness to benefit from aligning their specific aptitude(s) with the treatment they receive. This potential can be developed towards an integrative metacognitive framework, which combines metacognitive dimensions as an intervention strategy and self-regulation as a personal aptitude that will mutually transfer and reinforce learning outcomes (Schuster et al., 2020; Stebner et al., 2022).

This relationship better represents the control of cognitive processes that underlie and determine the use of complex cognitive strategies (Brick et al., 2015). They assume that metacognitive strategies increase the level of flexibility and vigour sufficient to be compatible with the prevailing concept of self-regulation (Amini et al., 2020). Self-regulated learners are good strategy users and relevant to metacognitive. They plan, set goals, select strategies, organize, self-monitor, and self-evaluate at various points during the process of acquisition (Dignath & Veenman, 2021). Learning science is one of the suggested fields of teaching integrating self-regulated learning (SRL) into metacognitive pedagogical practice (Michalsky, 2024).

2.4. Self-Efficacy

Self-efficacy is a judgment of a person's ability to plan and carry out actions that lead to the achievement of certain goals (Bandura, 2006). Self-efficacy also refers to someone’s beliefs to organize actions to achieve results. Simply, self-efficacy is a self-assessment of a person's competence to succeed in his or her tasks. It is a key factor in the source of human action because it influences the way a person chooses to act, the effort they put in, perseverance and resilience in facing obstacles and failure, the stress and anxiety they experience in conforming to environmental demands, and level of compliance they achieve (Schunk & DiBenedetto, 2021).

Self-efficacy is not a skill but rather a person's belief in the skills that can be carried out in certain situations (Tam, 2024). Self-efficacy is not only a prediction of behavior of willingness but also a belief in capability. Explicitly, the connection between self-efficacy with motivation and action, regardless of whether the belief is objectively true or not. Thus, behavior can be predicted through self-efficacy, although those behaviors can sometimes differ from actual abilities. Belief in one's abilities can help determine expected outcomes because the individual has confidence in anticipation of a successful outcome. Higher self-efficacy enhances interest and deep preoccupation, sets challenging goals, maintains strong commitment, and supports their efforts in the face of failure. Students with higher self-efficacy quickly and confidently recover after experiencing failure or setbacks. Self-efficacy theory predicts that students who have self-efficacy will be highly successful in solving problems (Ariff et al., 2021). Given the widespread use of self-efficacy as a predictor, it's critical to examine the variables that affect it as well, including attributive variables like self-regulation (H2) or specific cognitive features (H1).

2.5. Problem-Solving

Problem-solving is a complex thinking skill that uses a systematic process of identifying and processing information to find solutions to well-structured problems or constraints. Undeniably, problem-solving is the individual effort to find the best solution to a particular problem that is closely linked to the process of thinking. It requires a series of processes, including thinking strategies and control in every action, to acquire the right problem-solving approach (Jiang et al., 2020). To achieve an optimal problem-solving, it is necessary to utilize a well-organized solution by stages of problem recognition, plan formulation, plan execution, and reflection. By following a methodical approach and adhering to a set of procedures, individuals can achieve effective problem-solving. Additionally, they will develop a meticulously organized mindset to confront the problem that requires resolution. Thus, the utilization of cognitive and metacognitive is highly pertinent relevant and essential in problem-solving.

A multi-step problem solving requires the synchronization of many cognitive tasks and experiences, including the utilization of pre-existing information (facts, principles, and competencies) and problem-solving approaches (such as analysis and evaluation) (Sutama et al., 2021). In the process, problem-solving involves the metacognition component because it involves knowledge, experience and strategy functioning as tools for producing answers (Schudmak, 2014, Ozkubat). Problem-solving involves conceptual knowledge, including declarative knowledge about facts, theories, events, and objects, and procedural knowledge about motor skills, cognitive strategies, and cognitive strategies, which interact in various ways. Jonassen (2009) identified eleven problem types, categorized from more static and simpler (well-structured) to complex and dynamic (ill-structured). Primary schools tend to identify well-structured problem types like logic, algorithms, and story problems, which can be expanded into decision-making based on subject dynamics and student needs (Tachie, 2019) The three main individual differences affecting primary school students' problem-solving abilities are prior domain knowledge, prior experience, and cognitive skills, particularly in causal reasoning and epistemological beliefs (Rosenzweig et al., 2011). Thus, examining the metacognitive influence of primary school students on problem-solving (H3) can serve as a pathway to a potentially effective alternative educational intervention.

2.6. Correlation among Metacognitive Strategy, Self-Regulation and Self-Efficacy

It is still unclear whether metacognitive strategies enhance self-efficacy. Yet, several researches demonstrated that both metacognitive strategy and self-efficacy have a simultaneous influence on various areas, including learning techniques (Nosratinia et al., 2014) and critical thinking (Kozikoğlu, 2019). The mediation of other attitudinal elements is expected to enhance the direct impact of metacognitive on self-efficacy (Wajid & Jami, 2020). Therefore, it would be useful to obtain empirical support for the theoretical framework of motivational regulation. Moreover, factors related to motivation, such as self-efficacy enhance deep cognitive processing (Bandura, 1989; Zimmerman, 2000b). Thus, we predict that self-efficacy could be mediated by learning behaviors such as self-regulation, related to metacognitive strategy use and the use of deep-processing strategies (Akamatsu et al., 2019). It is assumed that there could be a reciprocal processing between the three aspects. This would imply the need for a methodological solution, to examine the causal relationship between self-regulation and metacognitive strategies to enhance self-efficacy (H5).

2.7. Correlation among Metacognitive Strategy, Self-Regulation, and Problem-Solving

Specifically, metacognitive strategies strongly influence problem-solving skills and quality of learning (Tachie, 2019). The learners could also solve problems more easily through group discussions and thinking about their own thinking. The importance of metacognitive strategy in problem-solving is shown from the research results that with metacognitive skills, students can focus more on solving problems managing the learning process, and solving scientific problems correctly to improve academic achievement (Safari & Meskini, 2016). Students with high metacognitive abilities will tend to do better problem-solving because they can plan and manage time, choose appropriate strategies, and provide understanding in learning (Kazemi et al., 2012). Plus they monitor learning progress by reflecting on the use of strategies, effective solutions, and self-efficacy when facing problems (Azizah & Nasrudin, 2018). Many previous research focus on the improvement of problem-solving skills with cognitive or metacognitive attributes such as learning disability or based on lack of outcome problem (Özkubat & Özmen, 2021), especially in mathematics (Anggo et al., 2021), but lack of them address the other subject matter problem and level of problem itself.

Metacognitive skills and self-regulated as well as problem-solving are intercorrelated (H6). The problem-solving and self-regulation somehow affected the metacognitive ability of students (Winarti et al., 2022). Additionally, Clarke and Roche (2018) showed that when people work on mathematical and science problems, they start to think about problem-solving. The urge to solve problems triggers ideas to prepare and plan strategies and solutions to problems. The ability to develop it is called self-regulation. Problem-solving, on the other hand, is a person's mental activity or conscious effort to find a solution and find a suitable solution. Science learning strongly covers the correlation. According to Fauzi and Sa'diyah (2019), introducing metacognition-based learning into physics learning can help students solve physics problems. Metacognitive control refers to mental activities to organize cognitive strategies to solve problems (Vula et al., 2017). When independent learning is practiced, students can increase their ability to be honest, independent, and brave.

2.8. The Present Study

The combination of metacognitive strategy and self-regulated learning encourages students to have new experiences and consider their strengths and weaknesses in studying science. In the end, both learning outcomes (self-efficacy and problem-solving), self-regulation, and metacognitive skills improve simultaneously. Previous research made self-efficacy a mediating factor (Ozturk 2023), but in this study, self-efficacy is seen as a learning outcome with problem-solving mediated through self-regulation. All the previous research conducted on upper-level students and the lack of them put into another aspect of intrinsic or mental such as self-efficacy as a target. Those all drive the researcher into a prospective urge to investigate the influence of metacognitive strategy and self-regulation on self-efficacy and problem-solving skills at the elementary school level.

The study utilized a model that aligns with the theoretical framework, as depicted in Figure 1. To evaluate this prediction model, the following hypotheses were examined:

H1: There is a significant influence of metacognitive strategy on primary school students' self-efficacy in science learning.

H2: There is a significant influence of metacognitive strategy on primary school students' problem-solving in science learning.

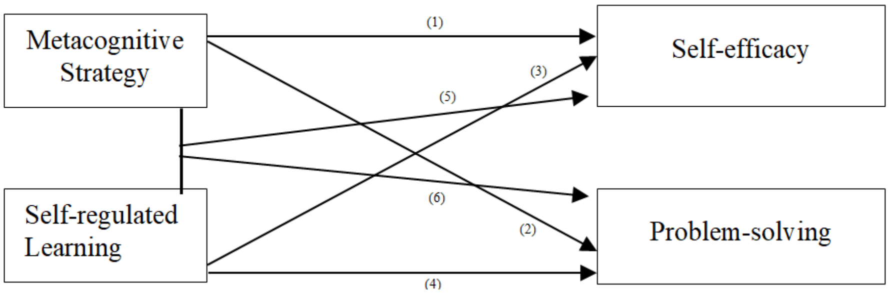
H3: There is a significant influence of self-regulation on primary school students' self-efficacy in science learning.

H4: There is a significant influence of self-regulation on primary school students' problem-solving in science learning.

H5: There is a significant influence of metacognitive strategy and self-regulation simultaneously on primary school students' self-efficacy in science learning.

H6: There is a significant influence of metacognitive strategy and self-regulation simultaneously on primary school students' problem-solving ability in science learning.

Figure 1
The estimation model of hypothesis



3. Method

3.1. Research Design

This research is a true experimental aimed to find a causal relationship between two factors that are deliberately treated and compare treatment and control that are not subjected to treatment conditions. A factorial design with Solomon's four-group type was used in this experiment to determine the effects of two or more independent variables interacting with the dependent variable (Gall et al., 2003). The objective is to determine the influence of the independent variable on the dependent variable separately and to test the interaction between two independent variables to each dependent variable. The design was 2 x 2 factorial since there are two levels in all variable categories, metacognitive strategy and self-regulated learning, which will compare the effects of the influence with the dependent variables (self-efficacy and problem-solving) (Ary et al., 2010).

3.2. Participants

The subjects were 5th grade elementary school students consisting of 4 classes in total with each 2 elementary schools from Surabaya and Sidoarjo. Each class consists of 25 totaling 100 students. This number will be divided into two experimental classes and two control classes. The subjects were selected based on purposive sampling with a strategy of homogeneity or similarity of research subjects.

3.3. Instruments

The data collection methods used were tests and questionnaires. The test to assess problem-solving is developed based on the assessment rubric. This four-scale Likert questionnaire is used to measure the level of students' self-regulation and self-efficacy. The instruments in this research used questionnaires and tests. The questionnaire in this research consists of self-efficacy and self-regulation variables. The scale used is a Likert scale between 1-4 (1 = very poor; 2 = poor; 3 = good; 4 = very good). The instruments in this research are to measure moderator variables and dependent variables. The adapted and developed instruments will be validated and reliable. The validity used in this research is content validity by subject matter expert and the reliability uses analysis with Cronbach's Alpha.

The ten self-efficacy instrument items show a score of .227, meaning that it was valid. While the results of the reliability test with Cronbach's alpha gained .626, because it is above .6, it can be stated that the self-efficacy instrument is reliable. Moreover, among the ten items, the Corrected Item-Total Correlation shows above .227, so it can be concluded that the self-regulated instrument is declared valid. The reliability of the self-regulated instrument shows a Cronbach's Alpha of .661, so it can be concluded that it is reliable. The test developed is a description test in the form of problem-solving in the science subject. The test was validated by experts in the field of science studies. The test developed is accompanied by an assessment rubric based on the problem-solving process. The thirteen problem-solving ability items show above .227, so it can be concluded that the instrument is valid. The reliability of the instrument is .628 so it can be declared very reliable.

3.4. Data Analysis

The SPSS 20 for Windows is used to analyze the data. The data analysis technique used in this research uses analysis of variance [ANOVA] because there was more than one factor whose interaction was considered. The assumption of multivariable normality and homogeneity of data variance are all set.

4. Results

The result of the four (4) variables investigated and the correlation can be seen from Table 1, Table 2 and Table 3 and the representation and discussion will be discussed in each section.

Table 1
Tests of between-subjects effects

Sources and dependent variable	*Type I Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Corrected Model					
Self-Efficacy	303.867[a]	3	101.289	16.346	<.001
Problem-Solving	60.490[b]	3	20.163	2.672	0.052
Intercept					
Self-Efficacy	65792.250	1	65792.250	10617.302	<.001
Problem-Solving	129528.010	1	129528.010	17163.132	<.000
Learning Strategy					
Self-Efficacy	278.890	1	278.890	45.006	<.001
Problem-Solving	50.410	1	50.410	6.680	0.011
Self-Regulated Learning					
Self-Efficacy	24.643	1	24.643	3.977	0.049
Problem-Solving	0.000	1	0.000	0.000	1.000
Learning Strategy * Self-Regulated Learning					
Self-Efficacy	0.334	1	0.334	0.054	0.817
Problem-Solving	10.080	1	10.080	1.336	0.251
Error					
Self-Efficacy	594.883	96	6.197		
Problem-Solving	724.500	96	7.547		
Total					
Self-Efficacy	66691.000	100			
Problem-Solving	130313.000	100			
Corrected Total					
Self-Efficacy	898.750	99			
Problem-Solving	784.990	99			

Table 2
Estimated marginal means of learning strategy variable

Dependent variable and learning strategy	*Mean*	*SE*	*95% Confidence Interval*	
			Lower Bound	*Upper Bound*
Self-Efficacy				
Metacognitive	27.076	0.384	26.314	27.839
Non-Metacognitive	23.768	0.392	22.990	24.546
Problem-Solving				
Metacognitive	35.143	0.424	34.301	35.984
Non-Metacognitive	36.857	0.433	35.998	37.716

Table 3
Estimated marginal means of self-regulated learning variable

Dependent Variable	*Mean*	*SE*	*95% Confidence Interval*	
			Lower Bound	*Upper Bound*
Self-Efficacy				
High-Self Regulated	25.968	0.295	25.381	26.554
Low- Self-Regulated	24.876	0.463	23.958	25.794
Problem-Solving				
High- Self-Regulated	35.993	0.326	35.346	36.640
Low- Self-Regulated	36.007	0.510	34.994	37.020

4.1. The Influence of Metacognitive Strategies on Self-efficacy

The results of Table 1. on the learning strategy variable with the dependent variable of self-efficacy showed a score of significance which means that there is a difference in self-efficacy between students with metacognitive and non-metacognitive strategies. The mean score indicated that students who are taught using metacognitive strategies are better at acquiring self-efficacy (27.076 >23.765).

The research results show that students who are taught with metacognitive strategies have self-efficacy better than students taught non-metacognitive strategies. One part of the metacognitive strategy is self-questions which help students to check understanding before learning (Šafranj, 2019). Metacognitive strategies have an impact on increasing student self-efficacy and achievement in learning (Ahangari & Mohseni, 2016). Previous research results also show that metacognitive strategies have a positive effect on self-efficacy. Self-efficacy relates to students' confidence in achieving learning goals (Amal & Mahmudi, 2020). In metacognitive strategies, students are taught how to achieve their learning goals through planning and monitoring their level of achievement. Self-efficacy is the foundation for motivation and self-achievement.

Metacognitive strategies are tools that help students learn independently by asking themselves questions and engaging in systematic internal dialogue. These strategies increase self-confidence in completing learning tasks and provide students with confidence in their abilities. The process of metacognitive strategies, which includes planning, implementing, monitoring, and evaluating, influences students' self-efficacy, a construct obtained in the learning environment. Self-confidence is crucial for students to believe in their abilities and make correct decisions (Khellab et al., 2022). Metacognitive strategies boost students' confidence in their thinking process and their courage in conveying their learning results. Zimmerman (2000b) explains that self-efficacy directly impacts students' learning methods and motivation processes. Teachers' positive reactions to student success promote self-efficacy (Jamil & Mahmud, 2019). Learning with metacognitive strategies helps students plan their learning and monitor problem-solving effectively. These strategies help students think and remember, proving that even young children can have a purpose in their activities (Stephanou & Mpiontini, 2017).

4.2. The Influence of Metacognitive Strategies on Problem-solving Abilities

As can be seen from the Table 1, there is a difference in problem-solving abilities between students who take part in learning with metacognitive and non-metacognitive strategies. Contrary to self-efficacy, students with non-metacognitive strategies performed better in problem-solving abilities than metacognitive (see Table 2). In detail, the non-metacognitive strategy gained a 36.857 mean score thus the metacognitive groups gained only a 35.143 mean score.

The results of the research show that there are differences in problem-solving abilities between students who take part in learning with metacognitive and non-metacognitive strategies. Students who are taught with non-metacognitive strategies have better problem-solving abilities compared to students with metacognitive strategies. Metacognitive processes focus on self-awareness of the cognitive knowledge deemed necessary for effective problem-solving, and they direct and regulate cognitive processes and strategies during problem-solving (Braund & DeLuca, 2018). That is, successful problem solvers, consciously or unconsciously (depending on task demands), use self-instruction, self-questioning, and self-monitoring to gain access to strategic knowledge, guide strategy execution, and regulate strategy use and problem-solving performance.

4.3. Influence of Self-regulated Learning on Self-efficacy

The results on the tests of between-subjects effects show that there is a significant difference between high and low self-regulated learning in self-efficacy with sig. score of .049 < .05. Students who have high self-regulation tend to perform better self-efficacy compared to low self-efficacy students (Table 3). The high self-regulated students gained 25.968 compared to the low high self-regulated learning which gained 1.112 deficit (24.876).

The research results show there are differences in self-efficacy among students who have high and low self-regulation. Students with high self-regulated have better self-efficacy compared to students with low self-regulated learning. Zimmerman & Martinez-Pons (1990) identified three determinants of student success: processes, environment, and behavior. A positive environment can influence behavior and personality. Self-regulation during learning involves motivational beliefs, behavior, and metacognitive activities that are planned and adjusted to support goals. Low self-regulation can negatively impact student success (Schunk & Zimmerman, 2012).

Self-efficacy is influenced by the environment, and a positive one can enhance one's capabilities. Students with self-regulated learning are better equipped to understand and evaluate their learning performance. Self-regulation involves self-reflective processes, where students evaluate their performance and make causal attributions. These causal attributions influence expectations of future success and emotional and behavioral consequences, highlighting the importance of the perceived causal dimension of achievement (Akpur, 2021). Self-efficacy is a stable trait that varies over time, depending on an individual's experience (Chen, 2022). This research suggests that elementary school students' problem-solving skills are influenced by their personal ability and effort, while self-regulation refers to their ability to learn independently, take initiative in diagnosing needs, formulate objectives, and evaluate outcomes (de Ruig et al., 2023). Self-regulation is highly relevant to self-efficacy because self-efficacy influences the level of challenge of the goals people set for themselves, the amount of effort they mobilize, and their persistence in the face of difficulties (Zimmerman et al., 1992).

4.4. The Influences of Self-regulated Learning on Problem-solving

Based on Table 1, problem-solving as the dependent variable of self-regulated learning gained sig. 1.00 > .05, meaning that there is no difference in problem-solving abilities between students who have high and low self-regulation. The low self-regulated students performed better problem-solving with a 36.007 mean score than the high self-regulated students with a 35.993 mean score.

The research results showed that there was no difference in problem-solving among students who have high and low self-regulated learning. Students with self-regulated high and low-ability problem-solving have similarities. These results indicate that during the learning or intervention process, students with low self-regulation experience development in problem-solving. Ifenthaler (2012) states that generic encouragement in self-regulation is an important aid in developing cognitive structures while solving problems. However, in this study, the dynamics of the two variables did not show a relationship due to several factors that will be discussed in the discussion section.

4.5. Interaction between Metacognitive Strategies and Self-regulated Students' Self-efficacy

The results of the tests of between-subjects effects on the interaction of learning strategy and self-regulated students toward self-efficacy show a significance value, .817 > .05. It can be concluded that H5 is rejected, which means there is no interaction between metacognitive and self-regulated learning on students' self-efficacy.

Table 4
Interaction between metacognitive strategy and self-regulated self-efficacy

Dependent Variable	Self-Regulation	Learning Strategy	Mean	SE	95% Confidence Interval	
					Lower Bound	Upper Bound
Self-Efficacy						
	High Self-Regulated	Metacognitive	27.686	0.421	26.850	28.521
		Non-Metacognitive	24.250	0.415	23.426	25.074
	Low Self-Regulated	Metacognitive	26.467	0.643	25.191	27.742
		Non-Metacognitive	23.286	0.665	21.965	24.606

Figure 2
Estimated marginal means of self-efficacy

Based on Table 4, it shows that there is a confirmative pattern on mean score interaction between the 3 variables. The data then illustrated in Graphic 1 that there is no meeting between the two lines. This is following the results of calculating the Tests of Between-Subjects Effects, there is no interaction between learning strategies and self-regulation on students' self-efficacy. The research results show that there is no interaction between metacognitive strategies and self-regulated learning to self-efficacy. Metacognitive strategies are not moderated by self-regulated toward self-efficacy.

4.6. Interaction between Metacognitive Strategies and Self-regulated Students' Problem-solving Abilities

The results of the tests of between-subjects effects on learning strategy and self-regulated students across problem-solving show a significance greater than .05. Therefore, it can be concluded that H6 is accepted, which means there is no interaction between metacognitive and self-regulated strategies on problem-solving abilities.

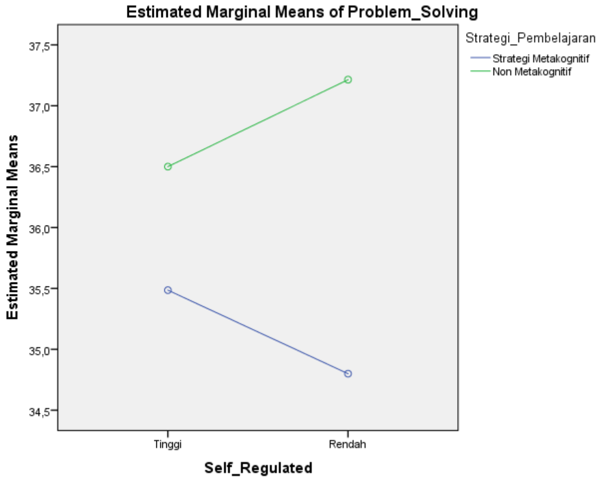
Table 5 shows the mean score of the two variables influenced differently to the problem solving with different gained mean scores so the interaction between the 3 variables could not be found. The data then illustrated in Graphic 2 that there is no meeting between the two lines. This is in accordance with the results of calculating the Tests of Between-Subjects Effects, there is no interaction between learning strategies (metacognitive) and self-regulation on students' problem-solving.

The results showed there was no interaction between metacognitive strategies and self-regulated learning to problem-solving ability (see Figure 3). Metacognitive strategies are not moderated by self-regulated to enhance problem-solving abilities. Metacognitive strategies tend to make students independent in their learning by monitoring their knowledge.

Table 5
Interaction between Metacognitive Strategy and Self-Regulated Learning to Problem-Solving

Dependent Variable	*Self-Regulated*	*Learning Strategy*	*Mean*	*SE*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
Problem-Solving						
High Self-Regulated						
Metacognitive Strategy			35.486	0.464	34.564	36.407
Non-Metacognitive			36.500	0.458	35.591	37.409
Low Self-Regulated						
Metacognitive Strategy			34.800	0.709	33.392	36.208
Non-Metacognitive			37.214	0.734	35.757	38.672

Figure 3
Estimated marginal means of problem-solving



5. Discussion

5.1. Evaluating Metacognitive Strategy to Enhance Problem-Solving

Metacognitive strategy is insufficient to predict problem-solving for primary school students. Primary school students tackle various problems, from structured textbook problems with clear goals and rules to everyday problems that require multiple solutions, multiple paths, or no solution at all (Haberkorn et al., 2014; Jonassen, 2009). Metacognition is still crucial for children in problem-solving, as it helps students explain and reconcile solutions, and monitoring metacognitive strategies helps them understand their learning process, as success depends on their ability to explain and reconcile solutions (Baas et al., 2015). In this research, students still needed help in monitoring their learning process. While in the non-metacognitive strategy, the teacher guides the learning process or monitors externally.

Metacognitive strategies for primary school students in their implementation require guidance during the learning process. The ability to monitor knowledge and evaluate understanding needs intensive guidance. Changes in the learning strategies used by students require a process of guidance and understanding in implementing metacognitive strategies. Besides, the intrinsic motivation factors were assumed to greatly influence the use of metacognitive strategies (Rieser et al., 2016).

5.2. Evaluating Self-Regulated Learning to Enhance Problem-Solving

The results demonstrate that students' problem-solving skills cannot be solely influenced by self-regulated learning. This finding is in direct opposition to certain prior research (Kistner et al., 2010; Vosniadou et al., 2024). Nevertheless, it is evident that self-regulated learning plays a compensatory function by ideally enhancing learning processes, but still relying on the efficiency of learning strategies that involve students and boost self-confidence (Kim et al., 2023; Losenno et al., 2020). There are other factors that could impact this. Other research found that emotional abilities moderate self-regulation (Ha, 2023). Relying on the assumption that primary school students' emotional skills are underdeveloped will have an impact on the science learning task of solving problems.

Self-regulated learning involves planning and adjusting motivational beliefs, behavior, and metacognitive activities to support goals. Group-based learning strategies can significantly boost self-confidence in completing assignments. It can be one of the alternative topics addressed in future research in the context of primary school science learning.

5.3. Evaluating Metacognitive and Self-Regulated Learning Interaction to Enhance Self-Efficacy

This result demonstrates that the influence of metacognitive techniques is reduced through self-regulated learning moderation. Although the metacognitive strategy has a negligible correlation with self-regulated learning, it can have a substantial impact on self-efficacy independently. This goes against the hypothesis, which states that a substantial interaction pattern between the three variables is anticipated. These findings indicate that other variables may have a more suitable function in increasing the influence of metacognitive strategy on the self-confidence of primary school students. Attitudinal attributions, such as self-regulated learning, may not be adequate as they share similarities with self-efficacy, which is commonly employed as a moderating factor. This outcome is a supplementary discussion that contradicts certain prior literature (Akamatsu et al., 2019; Guo, 2022; Wajid & Jami, 2020).

Furthermore, it is possible that the inclusion of self-efficacy as learning outcomes may not be suitable, as attributive behavior patterns that align with aptitude-treatment-interaction [ATI] should preferably focus on certain cognitive (Wang et al., 2023) and or psychomotor skills (Akpur, 2021) learning achievement. The role of self-regulated learning as a mediator for self-efficacy can be challenging, as the literature suggests that self-efficacy is more commonly seen as a means to enhance self-regulated learning (Putarek & Pavlin-Bernardić, 2020). The two attributions interact to enhance student involvement primarily on an emotional level such as engagement rather than a cognitive achievement (Cleary et al., 2021). In the future, it will be crucial to analyze how primary school kids employ self-regulated learning during the critical phase of information processing while choosing suitable learning strategies for non-cognitive learning outcomes.

5.4. Evaluating Metacognitive and Self-Regulated Learning Interaction to Enhance Problem-Solving

The result was contrary to the previouse references (Clarke & Roche, 2018; Fauzi & Sa'diyah, 2019; Vula et al., 2017) showed that students simultaneously improved their problem-solving by working with self-regulated and metacognition skills. The metacognitive strategy resulted the best performance at a significant level of cognitive. The negative interaction supports that elementary school students with non-metacognitive learning strategies can still perform even with a low level of self-regulation. This suggests that new experiences and students' strengths and weaknesses consideration in science at the elementary school cognition level are crucial. It has been proven in many studies that the success of teaching strategies requires the inclusion of metacognitive and self-regulatory processes (Blair et al., 2015; Cheung & Sonkqayi, 2023). However, the present results of the study indicate that the cognitive level is potentially more influential to some extent than the self-regulation mediator that students use when solving the problem.

It has been proven in many studies that effective teaching strategies require the inclusion of metacognitive and self-regulating processes (Blair et al., 2015; Krawec & Huang, 2017; Zhao, 2019). Based on the present study results, it can also be claimed that metacognitive strategies and self-regulate used by learners to control their actions, reason, and reflect, are not the only main resources of attention that they need when they are solving a problem (Ha et al., 2023).

Self-regulation is influenced by self-reinforcement, where individuals strengthen themselves depending on carrying out the desired response, while metacognitive strategies rely on self-awareness during the learning process so the possibility of combination or interaction is still potential. Primary school students in this research still depend on getting reinforcement from outside themselves. Self-regulated learning is a cyclical process involving personal, behavioral, and environmental factors that change during learning. Bandura explained that self-regulation changes are the relative strength and temporal patterns that should be monitored and can be changed through (a) personal efforts to self-regulate, (b) behavioral performance outcomes, and (c) changes in an environmental context (Shi et al., 2024). Before learning by using metacognitive strategies, students often lack the ability to plan their work and monitor their problem-solving. They are limited in knowledge about cognitive phenomena and perform little monitoring of their memory, comprehension, and cognitive efforts. This hinders their ability to effectively solve problems.

6. Conclusion

This research found a difference in self-efficacy between students who take part in learning with metacognitive and non-metacognitive strategies. Students with metacognitive strategies are better at learning self-efficacy. The use of metacognitive strategy also affected the problem-solving abilities. Unfortunately, students with non-metacognitive strategies are better at problem-solving abilities. In terms of self-regulated, there is a positive correlation between self-regulated and self-efficacy. High self-regulated learning students tended to have high self-efficacy. Contrarily to problem-solving, there is no difference in problem-solving ability among students who have self-regulated high and low. Combining the two variables in analysis, it is found that there was no interaction between metacognitive strategies and self-regulated to self-efficacy as well as to problem-solving ability. Metacognitive strategies and self-regulated levels did not directly influence self-efficacy and problem-solving skills in elementary school students.

The researchers suggest that metacognitive strategies are suitable for increasing self-efficacy for elementary school students. Teachers could employ metacognitive strategies to build students' self-confidence. Implementing metacognitive strategies needs more time so students can independently monitor their level of knowledge and evaluate it. The process of mentoring and providing trust to students continuously is very necessary. Providing a positive environment is related to the formation of students' personalities. Separately, the use of metacognitive strategies has the potential to affect all factors of learning success but requires special treatment for problem-solving skills. Self-efficacy is related to motivation, metacognition, and self-regulation. So teachers should be concerned about low self-regulatory students strengthening to exercise self-control, learn independently, and have self-confidence. Problem-solving skills again need to be specifically investigated in the future since having another potential in learning science. In the future potential distractor and also mediator attributes on learning achievements. Evaluating potential mediator attributes and combining the attribute-treatment interaction will gain better patterns and suitable formulas to enhance specific learning situations, subjects, and achievements.

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