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The Effect of Self-Regulated Learning On Students' Critical Thinking Skills In PISA Mathematic Questions

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Abstract. *The purpose of this study is examining self-regulated learning's effect on students' critical thinking skills in solving PISA-based math problems. The method used quantitative, especially an ex post facto research of 10th-grade students of SMAN 4 Kota Tangerang as the subject, with a sample of 76 students selected through the simple random sampling technique. Data were collected from questionnaires and essay questions. Data analysis was performed with a simple linear regression test that met the classical assumptions. The hypothesis resulted in a value of 2,636 ($t_{calculated}$)>1,667 (t_{table}) with a significance value of 0,010 < 0,05 indicating of positive and significant impact between self-regulated learning and students' critical thinking skills on PISA mathematics questions with an effect of 8,6% and the remaining variation is attributed to other factors such as basic mathematical skills, mathematical literacy, instructional models and methods, the learning environment, and student's experience in solving contextual mathematics problem.*

Keywords: *Self-regulated learning; Critical Thinking Skills; PISA Mathematics.*

INTRODUCTION

Mathematics is a crucial foundation for the development of human resources, both in education and in life, because it cultivates the rational reasoning, problem-solving skills, and analytical thinking required in various aspects of life (Indrawati, 2023). This also helps prepare students for the demands of the 21st-century, which emphasize the development of the 4Cs: Communication, Critical Thinking, Collaboration, and Creativity (Ma'rifat & I Made Suraharta, 2024). These skills are essential for students to adapt to rapid changes in the modern world, solve complex problems, and make decisions independently. However, the reality of education in Indonesia shows that students tend to focus on memorization and final grades rather than on the process of critical thinking and in-depth problem-solving (Rahmandani et al., 2025). This situation is evident from the results of the PISA (Programme for International Student Assessment) survey organized by the OECD (Organisation

for Economic Co-operation and Development), in which Indonesia's average mathematics score was only 379 in 2018, then dropped to 366 in 2022 clearly below the OECD average of 472 (OECD, 2023b). These results indicate that the level of education in Indonesia still struggles to develop critical thinking skill and the implementation of mathematics in real-life situation.

Critical thinking is a skill that allows a person to think deeply in order to find the solutions or answers needed to solve complex problems (Ariani, 2020). According to Braun, critical thinking refers to a thought process that involves identifying problems, analyzing, evaluating, and interpreting information, synthesizing evidence, and drawing logical conclusions to solve a problem (Braun et al., 2020). Within the framework of 21st-century learning, critical thinking skill serve as an essential competency that helps students analyze information, evaluate opinions, and make sound decisions (Nurdina et al., 2024). This skill is relevant to PISA, which serves as a global benchmark for assessing the competencies of 15 year old students in math, science, and literacy, emphasizing the application of mathematical concepts in real-world situations rather than simple calculations, in order to develop students'critical thinking skill (OECD, 2023b). However, in practice, most students lack mathematical critical thinking skills, particularly on problems involving problem-solving, analyzing, evaluating, and drawing conclusions from information such as the PISA mathematics questions. This is evident not only from PISA survey results but also from a previous study by Rosmalinda, which found that 58.1% of students demonstrated low levels of critical thinking skill when answering PISA-style questions (Rosmalinda et al., 2021).

In Wulandari's study also noted that students' critical thinking skills are not yet fully developed, particularly in the areas of analysis, evaluation, and inference when addressing questions similar to those in the PISA assessment (Wulandari & Warmi, 2022). An interview with a 10th-grade mathematics teacher at SMAN 4 Kota Tangerang revealed that students tend to give up immediately when faced with math problems requiring critical thinking. The teacher said students usually give up right away and just guess the answers when they encounter story-based or reasoning problems because they are not used thinking deeply, this condition results in low

critical thinking abilities". And the teacher also stated that only about 20% of the students in a given class possess strong critical thinking skills. Students who possess strong critical thinking skills are those who remain enthusiastic and do not easily give up when they cannot answer a math problem, and who frequently ask questions during math lessons. The low level of critical thinking among these students is related to how they self-regulate their learning in response to their environment, a concept known as self-regulated learning (Setiyawan et al., 2024).

Self-regulated learning (SRL) is a concept in the psychology of education that encompasses students' ability to manage their own learning, including awareness of the cognitive abilities, motivation, and thinking strategies required to achieve set goals (Brenner, 2022; Munahefi et al., 2022). SRL means a process in which students actively make their own learning targets, choose methods, manage their progress, and check their learning outcomes on their own (Setiyawan et al., 2024). According to Zimmerman, SRL is a cyclical process that a learner actively regulates themselves through cognitive, motivational, and behavioral aspects to achieve learning goals. This process begins with the planning phase (forethought), where students set learning goals, strategies, and motivation; continues with the performance phase, which involves behaviors such as time management and metacognition (self-monitoring), and concludes with the self-reflection phase, during which students evaluate their learning outcomes and adjust their strategies (Olsen & Mehus, 2022). SRL is also a process in which an individual analyzes new information or learning experiences by utilizing previously acquired skills and knowledge (Kusmaharti & Yustitia, 2022). Students with strong SRL skills tend to be more competent in the learning process, able to manage obstacles, and reflective about their mistakes. Amalia and Muslih state that when students have intrinsic motivation, feel a sense of responsibility, and want to learn on their own initiative, this indicates that they possess learning autonomy (Ahmad Muslih, 2024; Amalia et al., 2022).

Several studies indicate that students' critical thinking skills improve as their self-regulated learning increases (Gusmawan & Priatna, 2021; Miatun & Khusna, 2020). In their study, Asmar and Delyana also stated SRL has a positive relations

with students' critical thinking skills (Asmar & Delyana, 2020). Therefore, SRL plays an important role in inmproving students' critical thinking skills, as they are not just passive receivers of information but are also able to manage and filter information independently. In the context of solving PISA mathematics problems, SRL is expected to help students plan solution strategies, assess the effectiveness of the methods used, and correct logical errors that arise during the thinking process (Untu et al., 2025). Thus, SRL not only builds learning autonomy but also promotes critical thinking when facing complex problems. SRL and critical thinking in the PISA context are particularly crucial amid ongoing educational reforms, such as the Merdeka curriculum, which prioritizes student-centered learning and the development of learning autonomy.

Research on SRL and critical thinking skills has been extensively studied. In the international literature, the integration of SRL has been proven to significantly foster critical thinking and problem solving abilities within specialized fields, such as in EFL-speaking classes (Kumar et al., 2023). Additionally, global researchers have highlighted that advanced self-regulation skills are vital for students to thoroughly navigate, monitor, and succeed in micro-level critical thinking assessments like the CLA+ International (Hyytinen et al., 2021). Several studies in Indonesia have examined the connection between SRL and critical thinking abilities as well as learning outcomes (Mahrufah & Rijanto, 2024). Furthermore, previous study on SRL and critical thinking skill has only used general mathematics problems (Anugraheni, 2023). However, studies examining the influence of SRL on studens' critical thinking skills through PISA based mathematics problems remain limited, particularly in the Indonesian context. Therefore, this study aims to address this gap by investigating the effect of SRL on students' critical thinking skill using PISA mathematics problems.

Based on the above description, the goal of this study to determine whether self-regulated learning influences students' critical thinking skills on PISA mathematics questions in high school. Through this study, it is hoped that it will enrich the understanding of the role of self-regulated learning during learning activities that impact students' critical thinking skills when faced with contextual

mathematical problems that require problem-solving, and contribute to educators placing greater emphasis on students' self-regulated learning.

RESEARCH METHOD

This study utilizes a quantitative method based on an ex post facto design aimed at investigate the influence of the variables self-regulated learning (X) and critical thinking skills (Y) among students without applying direct intervention. The study population consists of 76 tenth-grade high school students at SMAN 4 in Kota Tangerang during the 2025/2026 academic year, who were sample selected using simple random sampling. The research design applied was as follows:

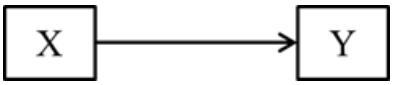


Figure 1. Research Desain

Data collection in this study employed two types of instruments: a questionnaire to measure students' self-regulated learning and essay test to measure critical thinking skills. The questionnaire consisted of 20 items adapted from an instrument developed by (Rusdi, 2025) based on Zimmerman's theory, which encompasses three dimensions: motivational, cognitive, and behavioral strategies. All items in the questionnaire were rated on a five-point Likert scale. To test the suitability of this adapted instrument, a content validity test was conducted through expert jugdement by mathematics education lecturers. The evaluation results indicated that the questionnaire was deemed suitable for use without revision.

Meanwhile, the test instrument for critical thinking skills uses five open-ended questions directly adopted from the 2012 and 2022 PISA international studies. Given that PISA questions have been tested for validity and reliability globally, an expert judgment test was also conducted in this study, focusing on content validity and language validation by mathematics and English education lecturers regarding alignment with indicators, language culture, and the readability level for students as research subjects. The results of the expert review indicated that the PISA essay questions met the criteria for use following minor revisions.

The collected research data was then tested for normality, linearity, and heteroscedasticity as requirements before hypothesis testing, and the data's suitability was also verified using SPSS version 27. A hypothesis test employing simple linear regression analysis was conducted to identify a significant positive connection between the two variables.

Table 1. Likert Scale Scores

Answer	Statement	
	Positive	Negative
SA (Strongly Agree)	5	1
S (Agree)	4	2
N (Neutral)	3	3
D (Disagree)	2	4
SD (Strongly Disagree)	1	5

In Table 1 above are the Likert scale scores used to measure the variable of self-regulated learning in the questionnaire, which includes five response options. To avoid response bias, the instrument was designed using both positive and negative statements with opposite scoring weights.

Table 2. Indicators of Self-Regulated Learning

Dimension	Indicator
Cognitve Strategy	Goal targeting and Preparation
	Rehearsing and Thinking
	Organizing and Converting
	Evaluate yourself
Motivational Strategy	Self-consequence
	Seeking social assistance
	Environmental controlling
Behavioral Strategy	Recording and monitoring
	Searching for Information
	Checking records
	Other/help seeking

(Meilani et al., 2018)

The self-regulated learning instrument used in this study was developed based on the three strategies shown in Table 2. There are a cognitive strategies that focus on the thinking process, ranging from planning to the independent evaluation of learning outcomes. Next, the motivational strategy encompasses students' efforts to build internal drive and foster an enabling environment to maintain consistency in learning. Finally, the behavioral dimension refers to students' concrete actions in managing resources and academic information.

Table 3. Indicators of Critical Thinking Skills

General Indicators	Sub-Indicators
Interpretation	Identify the issue in the question by accurately writing down the information provided and the questions asked
Analysis	Illustrate the relationship between information, questions, and concepts within a mathematical model and provide logical explanations
Evaluation	Use the proper method when solving problems and calculate carefully, in detail, and accurately
Inference	Making accurate conclusions based on the results of the solution

(Rosmalinda et al., 2021)

The critical thinking assessment tool adapted to the context of PISA mathematics questions includes four general indicators: interpretation, analysis, evaluation, and inference. Each of these indicators has specific focuses and objectives, as shown in Table 3 above.

RESULT AND DISCUSSION

The analysis process began by a descriptive analysis to get an outline of the data spread of SRL scores and critical thinking skills among the 76 respondents, before moving on to the hypothesis testing stage.

Table 4. Descriptive Statistics on Self-Regulated Learning and Critical Thinking Skills

	N	Minimum	Maximum	Mean	Std. Deviation
Self Regulated Learning	76	48	89	69,08	8,740
Critical Thinking Skills	76	6	14	9,67	2,223
Valid N (listwise)	76				

As shown in Table 4, the average SRL score is 69,08 with a standard deviation of 8,740 , where the lowest respondent score is 48 and the highest is 89. Meanwhile, the critical thinking ability variable had a average of 9,67 and a std. deviation of 2,223 , with lowest score of 6 and highest score of 14 out of a total score of 20.

Next, the required tests were conducted, namely the normality, linearity, and heteroscedasticity tests; the results are as follows.

Table 5. The Results Of The Normality Test

One-Sample Kolmogorov-Smirnov Test

			Unstandardized Residual
N			76
Normal Parameters[a,b]	Mean		,0000000
	Std. Deviation		2,12589601
Most Extreme Differences	Absolute		,085
	Positive		,085
	Negative		-,057
Test Statistic			,085
Asymp. Sig. (2-tailed)[c]			,200[d]
Monte Carlo Sig. (2-tailed)[e]	Sig.		,187
	99% Confidence Interval	Lower Bound	,177
		Upper Bound	,197

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

The assumption of normality is met if the significance value of the normality test exceeds 0,05. In Table 5, the sig. value obtained is 0,200 > 0,05 , indicating that the data are normally distributed.

Following this, the linearity test evaluates whether a linear relationship exists with the self-regulated learning variable (X) and the critical thinking skills variable (Y).

Table 6. The Results of Linearity Test

			Sum of Squares	df	Mean Square	F	Sig.
Critical Thinking Skills* Self Regulated Learning	Between Groups	(Combined)	136,076	31	4,390	,823	,713
		Linearity	31,819	1	31,819	5,965	,019
		Deviation from Linearity	104,258	30	3,475	,652	,890
	Within Groups		234,700	44	5,334		
	Total		370,776	75			

Based on Table 6 of the linearity test, the “linearity” row shows sig. value of 0,019 (< 0,05), indicating a linear relationship, while the sig. “deviation from linearity” value of 0,890 (> 0,05) indicates that the data does not deviate from a straight line. Thus, the relationship between self-regulated learning and critical thinking skill is a significant linear relationship.

After the linearity assumption is confirmed, the next step is to test for heteroscedasticity to determine whether the residuals from the regression model has the same variance for every value of the independent variable. If the variances of the residuals are constant, this indicates homoscedasticity (i.e., no heteroscedasticity) and if they are not constant, this indicates heteroscedasticity.

The appropriate regression model is one without heteroscedasticity (homoscedasticity) (Wijaya et al., 2018). In this test, the Glazer test is applied with a significance level of > 0,05, indicating the absence of heteroscedasticity.

Table 7. The Results of Heterocedasticitas

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	1,111	1,044		1,064	,291
	Self Regulated Learning	,010	,015	,076	,654	,515

a. Dependent Variable: RES1

The table above shows the sig. value of the SRL is 0,515 , which exceeds 0,05, it is determined that there is no heteroscedasticity and that the data exhibit homoscedasticity. Consequently, the residual variance is constant, allowing us to proceed with building the regression model.

The next step is to test the hypothesis regarding whether variable X significantly impacts on variable Y.

Table 8. The Results of Regression Equations and t-Test

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	4,523	1,969		2,298	,024
	Self Regulated Learning	,075	,028	,293	2,636	,010

a. Dependent Variable: Critical Thnking Skills

Based on the statistical output in the table, the resulting regression equation is $Y = 4{,}523 + 0{,}075X$. The constant in this equation is 4,523, meaning that if the self-regulated learning variable is zero, the value of the critical thinking ability variable is 4,523. If the regression coefficient of the self-regulated learning variable increases by 1 unit, the critical thinking ability variable will increase by 0,075. A positive value for the regression coefficient indicates that self-regulated learning has a positive impact on critical thinking skill.

The t-test in Table 8 shows that the score of t-calculated = 2,636 is higher than the t-table = 1,667, and the significance level is 0,01 < 0,05. This indicates that self-regulated learning has a significant positive impact on students' critical thinking skills in PISA-style mathematics questions.

Table 9. The Value of R Square

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,293[a]	,086	,073	2,140

a. Predictors: (Constant), Self Regulated Learning

A coefficient to determination (R^2) analysis wa employed to see how closely these two variabels are linked. Based on Table 9, the resulting R^2 of 0,086, suggests that self-regulated lerning is responsible for only 8,6% of the differences in students' critical thinking skills. Meanwhile, the rest 91,4% is attributed to other aspects that were not observed in this research.

The study's findings indicate that the variable of SRL has a significant and positive impact on students' critical thinking skills in PISA mathematics questions. This positive relationship indicates that an increase in self-regulated learning will be accompanied by an increased ability to think critically among students. These findings are further supported by Mahrufah's earlier research, which revealed that SRL has a significant positive effect on critical thinking skills and learning outcomes; students with high levels of SRL are able to analyze problems critically and achieve optimal learning outcomes. The findings also revealed that self-

regulated learning plays a role in students' ability to make sound decisions, identify problems, and find solutions in a logical and systematic manner, as well as to convey information clearly and effectively (Mahrufah & Rijanto, 2024).

However, self-regulated learning accounts for only 8,6% of students' critical thinking skills. Although this percentage is relatively small, its contribution remains significant. This indicates that self-regulated learning is a factor that has a real impact on critical thinking skills, particularly when solving PISA-based math problems that require advanced reasoning. Although it is only 8,6%, this is enough to show that there is an influence that can inform for devolopment learning systems with more emphasis on independent learning.

Meanwhile, for the 91,4% influenced by factors other than SRL, the researchers suspect that several other factors may also influence critical thinking skills. First, basic mathematical skills such as an understanding of concepts and procedures are crucial to the critical thinking process, because without a solid grasp of these concepts, students will struggle to analyze and evaluate information. This hypothesis is supported by Awaluddin's research, which states that foundational mathematical skills play a role in developing students' critical thinking skills, as these foundational competencies serve as the basis for understanding and processing mathematical concepts. Students who have a strong command of foundational mathematical skills generally demonstrate more effective critical thinking skills than students with weaker foundational mathematical competencies (Awaluddin et al., 2024).

Second, reading literacy is believed to influence critical thinking skills such as mathematical reasoning and contextual problem-solving, given that PISA math questions are presented in the form of complex story contexts. Students with poor reading skills tend to struggle to understand the intent of the questions. This is supported by an OECD report in the PISA study, which shows that reading literacy is closely linked to students' success in solving complex math problems (OECD, 2023a).

In addition, external factors such as learning models and methods also influence critical thinking skills. In their study, Wildana and Wiyastiti explain that

learning that remains focused on rote memorization tends to limit students' opportunities to develop analytical and evaluative skills; therefore, a learning model that fosters the development of critical thinking is needed specifically the 5E Learning Cycle model in which students are required to actively engage in exploring and understanding each concept studied throughout the learning process (Widana & Widyastiti, 2023). The learning environment, whether at home or at school, can also influence the development of critical thinking skills (Masithoh et al., 2025; Wahyuningtyas et al., 2023). Another possible explanation is that students lack experience in solving context-based problems (Winarni et al., 2024), such as the PISA math questions, so they are not yet accustomed to tackling problems that require in-depth reasoning, interpretation, and evaluation (Nasution et al., 2026). Other factors, such as physical condition, developing intelligence, and self-motivation, also play a role in shaping critical thinking skills (Rosmaini, 2023).

In the context of PISA mathematics questions, these factors are becoming increasingly important because PISA mathematics questions are designed to assess not only computational skills but also mathematical literacy in understanding the questions. PISA math questions require students to understand the context, formulate problems into mathematical models, solve them, and interpret the results. Therefore, self-regulated learning is not always a factor in critical thinking ability within the PISA context where it plays a role in helping students manage their learning strategies but other interrelated factors can also influence it, whether from cognitive, affective, or learning environment aspects. Thus, in developing critical thinking skills, it is not possible to focus only on one variable, but requires an approach that incorporates other variables.

CONCLUSION

Based on the tests conducted, this study concludes that students' critical thinking skills are positively and significantly effected by their self-regulated learning when answering PISA mathematics questions. This indicates that the better a student's self-regulated learning, the more optimal their critical thinking skills are when tackling contextual mathematics problems such as those in the PISA

assessment. Improvements in SRL are a statistically significant factor in determining students' success in critical thinking. Although SRL contributes only 8,6% to critical thinking ability, it remains a crucial element in education, where SRL must continue to be prioritized for student development to enhance learning quality particularly in improving critical thinking skills. Meanwhile, the remaining 91,4% of the influence is attributed to other factors such as basic mathematical ability, mathematical literacy, learning models and methods, the learning environment, and students' experience in solving contextual math problems. Therefore, for future researchers, it hope this study become a reference for further research that takes into consideration other factors that may influence critical thinking skills.

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