

**Self-Regulated Learning and Mathematical Anxiety in Relation to
Critical Thinking Ability**

Fitri Yani

Universitas Muhammadiyah Prof. Dr. Hamka

E-mail: fitriyani.mnf@gmail.com

Asih Miatun

Universitas Muhammadiyah Prof. Dr. Hamka

E-mail: asihmiatun@uhamka.ac.id

Submitted: 01-06-2024

Accepted: 13-06-2024

Published: 10-08-2024

Abstract

Mathematics has a significant positive impact on the advancement of science and technology, as well as the development of information and communication technologies. The purpose of this research is to investigate the relationship between self-regulated learning and mathematical anxiety in relation to students' critical thinking ability. This research was a quantitative analysis using a correlational method. This research's population encompassed 252 high scholars of a senior high school in Jakarta. The sample was recruited using the cluster random sampling technique, comprised 155 students. This study used a critical thinking ability test, along with non-test instruments including self-regulated learning and mathematical anxiety questionnaires. Multiple linear regression tests were performed in data analysis techniques by calculating the coefficients of determination and conducting hypothesis tests using F and T tests. The coefficient of determination output revealed that critical thinking ability was influenced by self-regulated learning and mathematical anxiety by 25.3%. The hypothesis testing outcomes using the F-test denoted a simultaneous influence of self-regulated learning and mathematical anxiety on learners' critical thinking ability. However, the partial hypothesis testing using the T-test indicated no relationship between students' critical thinking ability and self-regulated learning. At last, the T-test revealed a negative relationship between students' critical thinking ability and mathematical anxiety.

Keywords: self-regulated learning, mathematics, critical thinking

INTRODUCTION

Mathematics is a basic science that plays an important role in human life. The constant progress of science and technology cannot be separated from the role of mathematics. Mathematics makes a significant positive contribution to the advancement of science and technology, and plays a crucial role in the development of information and communication technology. Math is a common subject taught across all grade levels (Ismiati et al., 2021). Mathematics is a key contributor to Science and Technology /IPTEK due to its role in developing educational standards, which are crucial for fostering innovation (Hadi et al., 2020). Through curriculum modification and adjustment, the quality of education is significantly enhanced (Roslinda et al., 2022). Currently, the curriculum implemented is the Merdeka curriculum. (Puspita & Tirtoni, 2023). In the era of independent learning, critical thinking ability is essential for all individuals (Wangsa et al., 2021). In fact, a significant number of students struggle with mathematics because they do not comprehend it due to its involvement with numerous formulas, numbers, and abstract concepts (Ekawati, 2015). Learners with minimal critical thinking ability struggle to comprehend mathematical materials (Farisi et al., 2020). The lack of critical thinking skills in students is the factor that makes math material difficult to understand. Students' limited critical thinking skills make it difficult for them to understand mathematical concepts that are complex and require deeper analysis. Therefore, it is important for teachers to provide more specific guidance and training to improve students' critical thinking skills so that they can understand math materials better.

Critical thinking skills are the ability to process information and understand situations in a deeper and more analytical way. In critical thinking, students not only accept the information provided but also compare, evaluate, and interpret the information to make more informed and accurate decisions. Thus, critical thinking skills are essential in various aspects of students' lives, including education, career, and personal decisions. The results of research related to the low level of students' critical thinking skills in the 2013 curriculum include those conducted by Benyamin et al. (2021) mention that the critical thinking ability of 10th-grade learners fall within the category of below average, by 43,01%. Nurapipah & Zulkarnaen (2019) present their research showing that the mathematical critical thinking ability of 11th-grade high schoolers is classified as low. Subsequently, Prasetyo & Firmansyah (2022) assert that 12th-grade students still possess significantly low levels of critical thinking ability.

Students' critical ability is influenced by two main aspects, namely internal and external factors (Usman et al., 2020). An internal aspect that can enhance critical thinking ability is self-regulated learning, allowing students to independently manage their learning processes, thereby achieving learning objectives (Umami et al., 2023). Self-regulated learning is a situation where individuals who learn actively as the controller of their own learning activities, monitor motivation and academic goals, manage human and material resources, and become behavioral in the process of decision making and implementation in the learning process. In self-regulated learning, individuals actively take part in their learning process, both metacognitively, cognitively, motivationally, and behaviorally. This process involves stages such as planning, monitoring, controlling, and evaluating oneself systematically to achieve goals in learning. In educational activities, self-regulated learning is crucial as it can assist students in developing independent learning abilities, including time management, self-directed learning, and designing learning plans (Dinata et al., 2016). The results of relevant research related to the low level of students' self-regulated learning conducted in the 2013 curriculum include those

conducted by Febriyanti & Imami (2021) students possess a very low level of self-regulated learning, averaging a total of 28,96%. Furthermore, Kurnia & Warmi (2020) stated that students still show a low level of self-regulated learning, particularly in the planning stage.

Agustina et al. (2019) posits that mathematical anxiety includes among multiple factors impacting learners' ability to engage in critical mathematical thinking. Students who consistently experience anxiety throughout the learning process will likely see an impact on their mathematical skills. Mathematical anxiety cannot be taken lightly because learners' inability to adjust to lessons leads to challenges, fears, and ultimately hinders academic achievement (Anita, 2014). Students often experience mathematical anxiety that can even affect their perspective of mathematics (Hadi et al., 2020). Math anxiety is the feeling of anxiety experienced by some individuals when facing mathematical problems. Various factors can cause this anxiety, such as lack of ability to solve problems, bad experiences in class, and low self-confidence. Math anxiety can be a feeling of fear, tension, or anxiety that affects students' ability to understand mathematical concepts and solve problems. The results of relevant research related to the high ability of mathematical anxiety experienced by students in the 2013 curriculum were carried out by Supriatna & Zulkarnaen (2019) reveals that excessive mathematical anxiety is still experienced by a significant number of students with high and very high classifications. Moreover, over half of the grade IX students experience mathematical anxiety, ranging from severe to high levels (Fadilah & Munandar, 2020). Additionally, Wardani (2021) states that learners experience a high level of mathematical anxiety.

As noted by Ghimby (2019), learners with high level of self-regulated learning also possessed exceptional critical thinking ability. Miatun & Khusna (2020) stated that learners with substantial self-regulated learning showed expertise in critical thinking ability. According to Roslinda et al. (2022), the simultaneous positive impact of self-regulated learning on the critical thinking ability of was 43,2%. Next, Umami et al. (2023) noted that learners with a high level of self-regulated learning had stronger critical thinking ability compared with learners with a low level of self-regulated learning. Fifari & Winarso (2020) mentioned that mathematical anxiety had a relatively small impact on students' critical thinking ability, at 13,20%. Furthermore, Arpin et al. (2015) a found negative correlation between mathematical anxiety and critical thinking. Learners with low anxiety scored highest 57,14, while those with high anxiety scored lowest 23,33. Subsequently, Makrufah (2022) conclude that learners with low mathematical anxiety possess better critical thinking ability compared with learners with high mathematical anxiety.

As presented, the researchers aimed to conduct an analysis at a public high school in Central Jakarta. This research was carried out when the curriculum transitioned from the 2013 curriculum to the Merdeka curriculum. Therefore, the researchers were interested in conducting an examination of self-regulated learning and mathematical anxiety in relation to critical thinking ability of high schoolers. The data analysis techniques in this analysis were: (1) classic assumption tests, including normality, heteroscedasticity, and multicollinearity tests; and (2) hypothesis testing analysis utilizing multiple linear regression test, determination coefficient, F-test, and T-test. This inquiry's hypothesis applied a significance level of 5% and comprised three hypotheses.

Hypothesis 1

H₀: Self-regulated learning and mathematical anxiety had no simultaneous relationship with students’ critical thinking ability.

H₁: Self-regulated learning and mathematical anxiety had simultaneous relationships with students’ critical thinking ability.

Hypothesis 2

H₀: Self-regulated learning had no relationship with students’ critical thinking ability.

H₁: Self-regulated learning had a relationship with students’ critical thinking ability.

Hypothesis 3

H₀: Mathematical anxiety had no relationship with students’ critical thinking ability.

H₁: Mathematical anxiety had a relationship with students’ critical thinking ability.

METHOD

This research was a quantitative study using a correlational analysis technique. Correlational analysis is a statistical data analysis technique applied to examine the association between two or more variables that can be measured quantitatively (Hasbi et al., 2023). A cluster random sample of 155 tenth-grade students from a Central Jakarta senior high school was drawn from a population of 252 students. This analysis employed two independent variables: self-regulated learning (X₁) and mathematical anxiety (X₂), and one dependent variable: critical thinking ability (Y).

The study utilized questionnaires to assess the independent variables of self-regulated learning and mathematical anxiety. In measuring critical thinking ability, a test was administered. A trial was completed prior to employing the analysis instruments. Subsequently, the researchers evaluated the instruments’ validity and reliability. Critical thinking ability indicators utilized were proposed by Facione (Safitri & Miatun, 2021). The self-regulated learning questionnaire consisted of 27 statements developed based on the eight indicators proposed by Sweller et al. (2007). The mathematics anxiety questionnaire consists of 28 statements structured according to four indicators as proposed by (Mahmood & Khaton, 2011) adapted from Istiqomah & Miatun (2022). The analysis guidelines utilize the formulas presented in Table 1 (Yuniarti et al., 2023).

Table 1. Guidelines for Data Description Categories

Range	Category
$X > Mi + 1,5 SDi$	Very High
$Mi + 0,5 SDi < X \leq Mi + 1,5 SDi$	High
$Mi - 0,5 SDi < X \leq Mi + 0,5 SDi$	Moderate
$Mi - 1,5 SDi < X \leq Mi - 0,5 SDi$	Low
$X \leq Mi - 1,5 SDi$	Very Low

This research design employed a double paradigm with two independent variables. In this study, there were two independent variables and one dependent variable. This paradigm allowed analyzing the relationship between two independent variables and the dependent variable together. Thus, this study was able to determine how the two independent variables related to the dependent variable. Figure 1 below illustrates the design of this research.

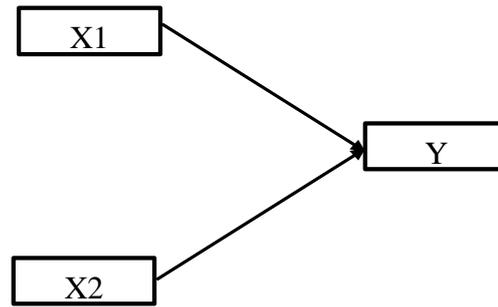


Figure 1 Research Design

Notes:

X₁ = Self-Regulated Learning

X₂ = Mathematical Anxiety

Y = Critical Thinking Ability

FINDINGS AND DISCUSSION

Description of Research Data

Descriptive data analysis was conducted by calculating the number of students and their proportions at each category level. The following provides an explanation of the data of each variable collected at one particular senior high school in Jakarta. Table 2 presents the descriptive data of self-regulated learning.

Table 2. Descriptive Analysis of Self-Regulated Learning Data

Value	Frequency	Percentage	Category
$X > 118$	7	4%	Very High
$110 < X \leq 118$	18	11%	High
$102 < X \leq 110$	38	23%	Moderate
$94 < X \leq 102$	53	32%	Low
$X \leq 94$	49	30%	Very Low

Based on the Table 2, it reveals that most high scholars exhibited a low level of self-regulated learning. This calls for improvement, as 30% of students belong in the very low category. This aligns with the conclusion of Hadayana et al. (2023), which notes that learners generally possess minimal self-regulated learning competence. Subsequently, Ghassani et al. (2023) highlight the persistent low level of self-regulated learning among learners in mathematics. Table 3 displays the data description of the mathematical anxiety variable according to the classifications.

Table 3. Descriptive Analysis of Mathematical Anxiety

Value	Frequency	Percentage	Category
$X > 93$	10	6%	Very High
$81 < X \leq 93$	39	24%	High
$68 < X \leq 81$	66	40%	Moderate
$56 < X \leq 68$	33	20%	Low
$X \leq 56$	17	10%	Very Low

Referring to Table 3, the majority of students exhibited moderate level of mathematical anxiety. This outcome aligns with the analysis by Juliyanti & Pujiastuti (2020), which indicates that most learners fall within the moderate category. Hakim & Adirakasiwi (2021) further-state that students' mathematical anxiety level is categorized as moderate. Table 4 displays the categories of critical thinking ability.

Table 4. Descriptive Analysis of Critical Thinking Ability

Value	Frequency	Percentage	Category
$X > 78$	58	35%	Very High
$66 < X \leq 78$	42	25%	High
$54 < X \leq 66$	41	25%	Moderate
$42 < X \leq 54$	17	10%	Low
$X \leq 42$	7	4%	Very Low

In line with the Table 4 revealed that students exhibited a high level of critical thinking ability in mathematics, as evidenced by the presence of 35% of high schoolers in the very high category and 25% of high schoolers in the high category. This finding aligns with the analysis conducted by Syafruddin & Pujiastuti (2020), which indicates that 62,2% of students exhibit very high critical thinking ability in mathematics, while 24,3% exhibit high ability. Subsequently, Anita & Firmansyah (2022) indicate that students exhibit critical thinking ability with 40% falling within the very high category and 30% falling within the high category.

Classical Assumption Tests

Normality Test

A normality test determines if the collected data exhibits a normal distribution (Sintia et al., 2022). In this analysis, the Kolmogorov-Smirnov technique was utilized to conduct the normality test. Table 5 displays the normality test output.

Table 5. Normality Test Output

Model	Test Statistic	Asymp. Sig. (2-tailed)	Conclusion
Unstandardized Residual	0,045	0,200 ^{cd}	Normal Distribution

From the Table 5, the significance value Asymp. Sig. (2-tailed) was 0,200, which was above the significance level of 0,05. Based on the criteria of Kolmogorov-Smirnov normality test, the data followed a normal distribution.

Multicollinearity Test

A multicollinearity test examines a significant correlation among independent variables (Alfiah et al., 2020). Table 6 presents the multicollinearity test output:

Table 6. Multicollinearity Test Output

Correlation	Tolerance	VIF	Conclusion
X_1 dan X_2	0,653	1,531	No Multicollinearity

Referring to the Table 6 above, the VIF value for the independent variables of self-regulated learning and mathematical anxiety was $1,531 < 10$. Thus, no multicollinearity between these two independent variables was identified.

Heteroscedasticity Test

A heteroscedasticity test examines an inequality in variances of predicted value errors (Puspa et al., 2021). Table 7 demonstrates the heteroscedasticity test output.

Table 7. Heteroscedasticity Test Output

	<i>P-Value</i>	Conclusion
Self-Regulated Learning	0,066	No Heteroscedasticity
Mathematical Anxiety	0,870	No Heteroscedasticity

From the Table 7, the Sig. value for the self-regulated learning variable was $0,066 > 0,05$, and the Sig. value for the mathematical anxiety variable was $0,870 > 0,05$. Therefore, there was no heteroskedasticity in this analysis.

Hypothesis Testing

Following the verification of classical assumptions through normality test, multicollinearity test, and heteroscedasticity test, hypothesis testing was conducted using multiple linear regression analysis, coefficient of determination, F-test, and T-test.

Multiple Linear Regression Equation

A multiple linear regression analysis identifies multiple independent variables' impact on a single dependent variable (Kolamban et al., 2020). The regression equation is displayed in Table 8 below.

Table 8. Multiple Linear Regression Equation

	B
(Constant)	101,487
Self-Regulated Learning	0,073
Mathematic Anxiety	-0,519

Table 8 shows the following values $b_1 = 101,487$, $b_2 = 0,073$, and $b_3 = -0,519$. Therefore, the resulting multiple linear regression equation was $Y = 101,487 + 0,073X_1 - 0,519X_2$. Hence, the functional relationship between self-regulated learning and critical thinking ability was positive, while the relationship between mathematical anxiety and critical thinking ability was negative. This implies that an improvement in self-regulated learning generates an enhancement in critical thinking ability, whereas an increase in mathematical anxiety generates a decrease in critical thinking ability.

Coefficient of Determination

Coefficient of determination test identifies independent variables' impact strength on a dependent variable (Lestariningsih & Sholichah, 2017). Table 9 displays the coefficient of determination test outcomes.

Table 9. Coefficient of Determination

Model Summary		
R	R Square	Adjusted R Square
503 ^a	0,253	0,244

Based on the Table 9, the value of R^2 was 0,253 or 25,3% when expressed as a percentage. As a result, critical thinking ability was affected by the variables self-regulated learning and mathematical anxiety to an extent of 25,3%. Previous research overlooked the influence of self-regulated learning and mathematical anxiety on critical thinking ability. Several earlier studies share similar variables. These studies include Ghimby (2019), who reveals a coefficient of determination of 29,6%, indicating that self-regulated learning positively affects student learning results and critical thinking ability. Gazali (2017) also reveals a coefficient of 9,1%, suggesting that mathematical anxiety and self-efficacy influence critical thinking ability.

The Relationship among Self-Regulated Learning, Mathematical Anxiety, and Students' Critical Thinking Ability

F-Test (Simultaneous Significance Test)

A simultaneous significance examined a simultaneous relationship among self-regulated learning, mathematical anxiety, and critical thinking ability variables. The simultaneous significance test output is available in Table 10.

Table 10. Simultaneous Significance Test Output

Calculated F	F-table	Significance F	Conclusion
27,451	3,05	0,000	Simultaneous Correlation

From the Table 10, it can be seen the f-value of 27,451 was said to be significant since the significance value (sig.) of 0,000 was below 0.05, or since the calculated f-value of 27,451 was above the f-table value of 3,05. This denotes the rejection of H_0 for hypothesis 1, further indicating that self-regulated learning and mathematical anxiety had simultaneous relationships with critical thinking ability. Previous analyses overlooked the simultaneous relationship among self-regulated learning, mathematical anxiety, and critical thinking ability. However, some previous studies share some similarities in terms of variables. For instance, Hastuti & Yoenanto (2019) note that self-regulated learning, mathematical anxiety, peer motivation, and social support from mathematics teachers have a simultaneous impact on students' mathematics achievement. Furthermore, Aryani & Hasyim (2018) mention that mathematical learning is simultaneously impacted by self-regulated learning, mathematical problem stress, and mathematical anxiety. The dependent variable in this analysis is critical thinking ability.

T-Test (Partial Significance Test)

A T-test (partial significance test) identifies partial effects of independent variables on dependent variables (Aidinoto, 2019). The partial significance test output is presented in Table 11.

Table 11. Partial Significance Test Output

	Calculated T	T-table	P-value
Self-Regulated Learning	0,563	1,974	0,574
Mathematic Anxiety	-5,640	-1,974	0,000

From the Table 11, the calculated t-value for self-regulated learning was 0,563, which was above the t-table value of 1,974. Additionally, a p-value of $0,574 > 0,05$ was obtained. The outcomes denote the acceptance of H_0 for Hypothesis 2, further indicating

no relationship between self-regulated learning and students' critical thinking ability. Existing literature did not establish that self-regulated learning lacks a substantial influence on critical thinking ability. Some studies have examined the relationship between self-regulated learning and critical thinking ability. Anugraheni & Adistana (2023) concluded that self-regulated learning positively influenced learners' critical thinking ability. Similarly, Gusmawan et al. (2021) noted that learners with a significant degree of self-regulated learning showed excellent thinking ability, while those with a low level of self-regulated learning possessed lower critical thinking ability. This study's findings do not align with previous research outcomes. This discrepancy can be attributed to several factors, such as differences in research methods, samples, or variables used. Therefore, further analysis is necessary to understand the differences between this study's findings and previous research outcomes. The calculated T-value for mathematical anxiety was -5,640, while the T-table value was -1,974. The calculated T-value was above the T-table value, and the p-value was $0,000 < 0,05$. Based on the results of data analysis in table 8, the linear regression equation of the data obtained is $Y = 101,487 + 0,073X_1 - 0,519X_2$. The negative X coefficient shows that math anxiety has a negative relationship with critical thinking skills.

This means that the higher the level of student anxiety, the lower the level of critical thinking ability. Several factors can cause the low results of critical thinking skills. First, students are accustomed to systematic problems that do not require critical thinking. Second, contextual questions that can improve critical thinking skills are rarely given. Third, students are not used to writing explanations when answering questions. And fourth, students lack understanding of the concept of row and sequence material. The statistics indicate the rejection of H_0 for Hypothesis 3, further indicating a substantial relationship between mathematical anxiety and critical thinking ability among students. This signifies a relationship between mathematical anxiety and students' critical thinking ability. On the other hand, students with higher anxiety levels likely have lower critical thinking ability. This is consistent with the analysis by Tasya et al. (2023), which reveals that, in terms of critical thinking ability, learners with low mathematical anxiety outperform those with moderate mathematical anxiety, and learners with moderate mathematical anxiety outperform those with high mathematical anxiety. This finding is further supported by Hakim & Adirakasiwi (2021), who note that student academic achievement is positively influenced by low levels of anxiety, while poor learning behavior is negatively influenced by high levels of anxiety. Subsequently, Arpin et al (2015) demonstrate in their study that learners with high mathematical anxiety typically exhibit low critical thinking ability, while learners with low mathematical anxiety typically exhibit high critical thinking ability. This result is consistent with several previous studies that demonstrate a negative relationship between mathematical anxiety and students' critical thinking skills. Students with higher levels of mathematical anxiety tend to have lower critical thinking skills, whereas students with lower levels of mathematical anxiety tend to have higher critical thinking skills. Based on the theoretical review above, it is clear that mathematical anxiety can instill fear, which ultimately hinders students' academic performance.

CONCLUSION

This research's aim is to identify self-regulated learning and mathematical anxiety in relation to students' critical thinking ability. The findings based on field data show that self-regulated learning belongs in the low category, mathematical anxiety falls within the moderate category, and critical thinking ability falls within the very high category. The coefficient of determination shows that critical thinking ability in high scholars is affected by the variables of self-regulated learning and mathematical anxiety by 25.3%. The hypothesis testing outcomes reveal that (1) self-regulated learning and mathematical anxiety have simultaneous relationships with students' critical thinking ability; (2) self-regulated learning has no relationship with students' critical thinking ability; (3) mathematical anxiety has a negative relationship with students' critical thinking ability. Referring to this study, it is recommended for teachers to monitor the anxiety levels of students so that a high level of anxiety can be avoided, because it can interfere with students' critical thinking ability. In addition, teachers are also advised to provide mathematical exercises to enhance students' critical thinking ability.

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