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The Role Of *Self Regulated Learning* In Mediating The Influence Of Generative AI Usage Intensity On Students' Learning Independence In Mathematics Learning

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Abstract

This study aims to analyze the influence of generative Artificial Intelligence (AI) usage intensity on students' learning independence through the mediating role of Self Regulated Learning (SRL) in mathematics learning. This research employed a quantitative approach with an ex post facto design involving 157 students of MAN 2 Sinjai selected through total sampling. Data were collected using questionnaires and analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4. The results indicate that generative AI usage intensity has a positive and significant effect on Self Regulated Learning ($\beta = 0.865$, $p < 0.001$), while Self Regulated Learning significantly influences students' learning independence ($\beta = 0.912$, $p < 0.001$). Furthermore, Self Regulated Learning was found to significantly mediate the relationship between generative AI usage intensity and learning independence. These findings suggest that the effectiveness of generative AI in promoting learning independence depends on students' ability to regulate their learning processes. Therefore, the integration of generative AI in mathematics education should be accompanied by strategies that strengthen students' self-regulation skills to maximize learning outcomes.

Keywords: Generative AI, Self-Regulated Learning, Learning Independence, Mathematics Learning.

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INTRODUCTION

The development of digital technology in the Industrial Revolution 4.0 and Society 5.0 eras has brought significant changes to various aspects of life, including education. One technological innovation that has developed rapidly in recent years is Artificial Intelligence (AI), particularly Generative Artificial Intelligence (Generative AI). This technology can generate various forms of content, such as text, images, audio, and problem-solving solutions based on user commands. The emergence of generative AI platforms like ChatGPT, Gemini, Copilot, and similar applications has transformed the way students access information, obtain explanations, and complete academic assignments (UNESCO, 2023).

In the context of education, generative AI offers a variety of opportunities to improve the quality of learning. This technology allows students to obtain instant feedback, access a wider variety of learning resources, and receive explanations tailored to each individual's learning needs. In mathematics learning, generative AI can help students understand abstract concepts through step-by-step explanations, the presentation of varied example problems, and the provision of alternative problem-solving strategies. These conditions make generative AI one of the innovations that has the potential to support more personalized, flexible, and adaptive learning (Dwivedi et al., 2023).

However, the use of generative AI in education also poses various challenges. The ease of obtaining quick answers has the potential to encourage students to rely on technology without engaging in in-depth thinking. If used inappropriately, generative AI can reduce students' cognitive engagement in the learning process and impair their ability to construct knowledge independently. Therefore, the use of generative AI in education needs to be examined not only from the perspective of the technology's benefits but also from the perspective of how it impacts students' learning behavior (Khalil & Er, 2024).

One important aspect of 21st-century education is independent learning. Independent learning is the ability of students to manage the learning process independently through planning, implementing, monitoring, and evaluating learning activities. Students with a high level of independent learning tend to be more active in seeking information, take responsibility for the learning process, and are able to make independent decisions in solving academic problems (Knowles, 1975). In mathematics learning, independent learning is crucial because learning success is determined not only by the ability to receive information, but also by the students' ability to actively and sustainably build conceptual understanding.

The relationship between the use of generative AI and independent learning is not always

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straightforward. The presence of technology does not automatically make students more independent in learning. On the other hand, the impact of using generative AI is greatly influenced by students' ability to manage the learning activities they undertake. Some students are able to utilize generative AI to deepen their understanding of concepts, find alternative solutions to problems, and reflect on their learning outcomes. However, others tend to use AI solely as a tool to obtain instant answers without conducting adequate analysis. This difference suggests that psychological mechanisms play a role in explaining how the use of generative AI can contribute to the development of independent learning.

One construct thought to play a significant role in this relationship is *Self Regulated Learning* (SRL). Zimmerman (2002) defines *Self Regulated Learning* as an individual's ability to actively regulate the learning process through planning, monitoring, controlling, and self-evaluating activities to achieve predetermined learning goals. From a social cognitive theory perspective, students with strong self-regulation skills tend to be more effective in utilizing available learning resources, including digital technology. Therefore, *Self Regulated Learning* is seen as a factor that enables students to transform the potential of technology into meaningful learning experiences.

Various previous studies have shown that the use of generative AI has a positive relationship with students' learning outcomes, learning motivation, learning engagement, and problem-solving abilities (Bozkurt et al., 2021; Wong & Yang, 2024). Other studies have also found that the use of generative AI can help students improve their self-regulation skills by providing rapid feedback and easily accessible learning resources (Mulyono & Anwar, 2023). However, some studies have suggested that excessive use of AI can lead to learning dependency and reduce students' cognitive engagement in the learning process (Khalil & Er, 2024).

Based on previous research reviews, most studies still focus on the direct influence of generative AI on learning outcomes, learning motivation, or student learning engagement. Meanwhile, research explaining the psychological mechanisms linking the use of generative AI to Self Regulated Learning is still relatively limited. In particular, studies that place *Self Regulated Learning* as a mediating variable in the relationship between the intensity of generative AI use and student learning independence in mathematics learning have not been widely found. Thus, there is still a research gap that needs to be studied further.

The novelty of this research lies in examining the role of *Self Regulated Learning* as a mediating variable in the relationship between the intensity of generative AI use and student learning independence. This study not only examines whether generative AI use influences

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learning independence but also explains how this influence occurs through improved student self-regulation abilities.

Based on the description, this study aims to analyze the influence of the intensity of generative AI use on *Self Regulated Learning* , the influence of *Self Regulated Learning* on learning independence, and the role of *Self Regulated Learning* in mediating the influence of the intensity of generative AI use on students' learning independence in mathematics learning.

RESEARCH METHODS

This study uses a quantitative approach with an ex post facto design to analyze causal relationships between variables that have occurred naturally without providing special treatment to respondents. The research was conducted on students of MAN 2 Sinjai who participated in mathematics learning. The quantitative approach was chosen because the research aims to test the influence of the intensity of the use of generative Artificial Intelligence (AI) on students' learning independence through the mediating role *of Self Regulated Learning* . The analysis of the relationship between variables was carried out with the help of SmartPLS software version 4.

The study was conducted at MAN 2 Sinjai in the 2025/2026 academic year. The study population consisted of all 157 students actively using digital technology in their mathematics learning process. Given the relatively limited population, the study employed a *total sampling technique* , thus all members of the population were selected as respondents. This technique was chosen to obtain a more comprehensive representation of the characteristics of the population studied. The research instrument used a closed questionnaire compiled based on the indicators of each research variable. The intensity variable of generative AI use is measured through indicators of frequency of use, duration of use, purpose of use, and utilization of AI in completing learning tasks. The *Self Regulated Learning* variable is measured through indicators of learning planning, learning strategy management, monitoring the learning process, and self-evaluation.

Meanwhile, the learning independence variable was measured using indicators of learning initiative, learning responsibility, decision-making ability in learning, and self-confidence in completing academic assignments. All instrument items were measured using a 4-level Likert scale, ranging from 1 (strongly disagree) to 4 (strongly agree). Before being used in the study, the instrument underwent content validation by experts and pilot testing to ensure the clarity and readability of each statement.

Data analysis was carried out through two main stages, namely evaluation of the measurement model (*outer model*) and evaluation of the structural model (*inner model*).

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Evaluation of the outer model includes testing convergent validity, discriminant validity, and construct reliability. Convergent validity was evaluated through outer loading and Average Variance Extracted (AVE) values, while construct reliability was evaluated using Composite Reliability and Cronbach's Alpha. A construct is considered to have convergent validity if its outer loading is ≥ 0.70 and AVE is ≥ 0.50, while construct reliability is considered good if its Composite Reliability and Cronbach's Alpha are ≥ 0.70 (Hair et al., 2022).

Next, an inner model evaluation was conducted to examine the relationship between latent variables through the coefficient of determination (R^2), path coefficient, and hypothesis significance testing using the bootstrapping procedure. The research hypothesis was accepted if the t-statistic value was greater than 1.96 and the p-value was less than 0.05 at a 5% significance level. The mediation effect was tested through specific indirect effects analysis to determine the role of *Self Regulated Learning* in mediating the relationship between the intensity of generative AI use and student learning independence.

RESEARCH RESULT

Evaluation of Measurement Model (Outer Model)

Measurement model evaluation was conducted to ensure that all research constructs met validity and reliability criteria. Test results showed that all variables had Average Variance Extracted (AVE) values above 0.50, and Cronbach's Alpha and Composite Reliability values above 0.70. Thus, all indicators were declared valid and reliable for measuring the research constructs.

Table 1. Results of the Validity and Reliability Test of the Constructs

Variables	Cronbach's Alpha	Composite Reliability	AVE	Information
Generative AI Usage Intensity (X)	0.963	0.967	0.714	Valid and Reliable
Self Regulated Learning (Z)	0.973	0.976	0.727	Valid and Reliable
Learning Independence (Y)	0.968	0.971	0.694	Valid and Reliable

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These results indicate that all constructs have met the requirements of convergent validity and construct reliability so that they are suitable for use in structural model analysis.

Structural Model Evaluation (Inner Model)

Evaluation of the structural model is carried out by testing the coefficient of determination (R^2) to determine the model's ability to explain endogenous variables.

Table 2. Value of the Coefficient of Determination (R^2)

Endogenous Variables	R^2	Category
Self-Regulated Learning	0.749	Strong
Learning Independence	0.832	Strong

The R^2 value of 0.749 indicates that 74.9% of the variation *in Self Regulated Learning* can be explained by the intensity of generative AI use. Meanwhile, the R^2 value of 0.832 indicates that 83.2% of the variation in learning independence can be explained by the intensity of generative AI use and *Self Regulated Learning* . These values indicate that the research model has strong predictive capabilities.

Hypothesis Testing

Hypothesis testing was carried out using the bootstrapping procedure in SmartPLS with significance criteria of p-value < 0.05 and t-statistic > 1.96.

Table 3. Hypothesis Testing Results

Relationship between variables	Path Coefficient (β)	T-Statistic	P-Value	Decision
Intensity of Generative AI Use → *Self Regulated Learning*	0.865	29,337	0,000	Accepted
Self Regulated Learning → Learning Independence	0.912	31,253	0,000	Accepted

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The test results show that the intensity of generative AI use has a positive and significant effect on *Self Regulated Learning* . In addition, *Self Regulated Learning* also has a positive and significant influence on students' learning independence.

Testing the Mediation Effect

Prior to discussing the mediating role of Self-Regulated Learning, it is necessary to examine the direct effect of Generative AI Usage Intensity on Learning Independence. This analysis aims to determine whether generative AI directly contributes to students' learning independence. The results are presented in Table 4 Direct Effect.

Tabel 4. Direct Effect

Relationship	β	T Statistics	P Values	Interpretation
AI Usage Intensity → Learning Independence	-0.034	0.289	0.772	Not Significant

The results indicate that Generative AI Usage Intensity does not have a significant direct effect on Learning Independence (β = -0.034; T = 0.289; p = 0.772). This finding suggests that the contribution of generative AI to learning independence occurs indirectly through Self-Regulated Learning.

Next, The mediation effect test was conducted to determine the role of *Self Regulated Learning* in bridging the relationship between the intensity of generative AI use and student learning independence.

Table 5. Indirect Effects

Indirect Relationship	Coefficient	T-Statistic	P-Value
Intensity of Generative AI Use → *Self Regulated Learning* → Learning Independence	0.382	2,879	0.004

The test results show that the indirect effect of the intensity of generative AI use on learning independence through *Self Regulated Learning* is positive and significant. These findings indicate that *Self Regulated Learning* acts as a mediating variable in the relationship between the intensity of generative AI use and students' learning independence.

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DISCUSSION

Evaluation of Measurement Model (Outer Model)

Evaluation of the measurement model was carried out to ensure that all indicators used were able to measure the research constructs validly and reliably. The test results showed that all indicators had outer loading values above the recommended minimum limit, thus meeting the convergent validity criteria. Furthermore, the Average Variance Extracted (AVE) value for each construct exceeded the minimum value of 0.50, indicating that the construct was able to explain more than 50% of the variance in the indicators used (Hair et al., 2022).

The results of the reliability test showed that all constructs had Composite Reliability and Cronbach's Alpha values above 0.70 . Thus , all research variables were declared reliable and suitable for use in further analysis. These results indicate that the instrument used has a good level of internal consistency in measuring the intensity of generative AI use, *Self Regulated Learning* , and student learning independence.

Structural Model Evaluation (Inner Model)

Structural model evaluation is carried out to determine the ability of the research model to explain the relationship between variables. The analysis results show that the coefficient of determination (R^2) for *the Self Regulated Learning* and learning independence variables is in the moderate to strong category. This finding indicates that the intensity of generative AI use is able to explain variations in students' *Self Regulated Learning* , while the combination of generative AI use intensity and *Self Regulated Learning* is able to adequately explain variations in students' learning independence.

Next, hypothesis testing was carried out using the bootstrapping procedure to determine the significance of the relationship between variables in the research model.

The Influence of Generative AI Usage Intensity on *Self-Regulated Learning*

Test results show that the intensity of generative AI use has a positive and significant effect on students' *Self Regulated Learning* . This finding suggests that the higher the intensity of generative AI use, the better students' ability to regulate their learning process.

The results of this study indicate that generative AI not only functions as a source of information, but can also be a tool that supports students' self-regulation activities. Through generative AI, students gain faster access to learning materials, alternative problem-solving methods, and feedback that can be used to evaluate their understanding. These conditions enable students to

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plan learning activities more effectively, monitor learning progress, and evaluate the learning outcomes obtained.

The findings of this study align with Zimmerman's (2002) theory *of Self Regulated Learning*, which states that self-regulation develops when individuals actively manage available resources to achieve learning goals. In the context of digital learning, generative AI can be viewed as a learning resource that supports self-regulation by providing easily accessible information, rapid responses, and personalized learning support.

The results of this study also align with various previous studies showing that the use of artificial intelligence-based technology can improve students' ability to manage learning activities independently. The presence of generative AI allows students to gain greater control over their learning process, thus encouraging the development of *Self Regulated Learning skills* .

The Influence of *Self Regulated Learning* on Learning Independence

The test results show that *Self Regulated Learning* has a positive and significant effect on students' learning independence. These findings indicate that students who have high self-regulation skills tend to have better levels of learning independence. Theoretically, *Self Regulated Learning* and learning independence are two interrelated concepts. *Self Regulated Learning* emphasizes students' ability to plan, control, and evaluate the learning process, while independent learning reflects students' ability to take responsibility for their own learning. Therefore , the better a student's self-regulation skills, the higher the level of independent learning they can achieve.

In mathematics learning, self-regulation skills are crucial because students are often faced with problems that require persistence, appropriate problem-solving strategies, and the ability to evaluate errors. Students who are able to effectively manage their learning process tend to be more confident in completing tasks and are less dependent on the help of others. This finding reinforces Zimmerman's (2002) theory, which places *Self Regulated Learning* as the primary foundation for developing independent learning behavior. Therefore, developing *Self Regulated Learning* needs to be a primary focus in the learning process to enhance student learning independence.

The Role of *Self Regulated Learning* in Mediating the Influence of Generative AI Usage Intensity on Learning Independence

The results of the indirect effect test show that *Self Regulated Learning* is able to mediate the relationship between the intensity of generative AI use and student learning independence.

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These findings suggest that the influence of generative AI on independent learning does not occur directly, but rather occurs through first improving students' self-regulation abilities. These results provide an understanding that technology does not automatically produce independent learning behavior. The presence of generative AI simply provides an information-rich learning environment and a variety of easily accessible learning resources. The positive impact of technology on learning depends largely on how students utilize it in their learning process.

In the perspective of Bandura's Social Cognitive Theory (1986), learning behavior is the result of interactions between individual factors, the environment, and the behavior itself. Generative AI can be viewed as an environmental factor that provides various learning opportunities. However, its successful utilization is determined by the individual's ability to regulate the learning process. Therefore, students with high levels *of self -regulated learning* will be more able to utilize generative AI productively than those with low self-regulation. The findings of this study indicate that students who use generative AI to understand mathematical concepts, find alternative solutions to problems, check for errors, and evaluate their work will experience greater benefits than those who only use AI as a tool to obtain instant answers. In other words, the benefits of generative AI for learning are not determined by how often the technology is used, but by how it is used to support self-regulation.

The results of this study also provide an explanation for why the direct influence of generative AI on independent learning is not always significant. Technology only functions as an aid , while the formation of independent learning is still determined by students' internal factors. When students have good self-regulation skills, generative AI can be a tool that strengthens the independent learning process. Conversely, if self-regulation skills are low, the use of generative AI has the potential to create dependence on technology. Thus, *Self Regulated Learning* acts as a psychological mechanism that bridges the relationship between the intensity of generative AI use and students' independent learning. This finding is an important contribution to research because it shows that the successful integration of generative AI in education depends not only on the technology itself, but also on students' ability to manage the learning process independently.

The findings reveal that Self-Regulated Learning plays a crucial mediating role in the relationship between Generative AI Usage Intensity and Learning Independence. Although the direct effect of Generative AI Usage Intensity on Learning Independence was not significant, the indirect effect through Self-Regulated Learning was found to be significant. This indicates that students do not automatically become independent learners merely by using generative AI.

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Instead, generative AI contributes to learning independence when students actively regulate, monitor, and evaluate their own learning processes.

CONCLUSION

This study aims to analyze the influence of the intensity of generative Artificial Intelligence (AI) use on students' *Self Regulated Learning and learning independence, and to examine the role of Self Regulated Learning* as a mediating variable in this relationship in mathematics learning. The results show that the intensity of generative AI use has a positive and significant effect on students' *Self Regulated Learning* . This finding indicates that the use of generative AI can support students' abilities in planning, monitoring, and evaluating the learning process. In addition, *Self Regulated Learning* has also been shown to have a positive and significant effect on students' learning independence. Thus, the better the self-regulation skills that students have, the higher the level of learning independence that can be achieved.

The main findings of the study indicate that *Self Regulated Learning* is able to mediate the influence of the intensity of generative AI use on students' learning independence. These results indicate that the benefits of generative AI in developing independent learning do not occur directly, but rather through improving students' self-regulation skills. In other words, generative AI will optimally contribute to independent learning if students are able to utilize the technology in a targeted, planned, and reflective manner during the learning process. Based on the research results, it can be concluded that the success of integrating generative AI into learning is determined not only by the intensity of its use, but also by students' ability to manage the learning process independently. Therefore, the development of *Self Regulated Learning* is an important factor that needs to be considered in the implementation of generative AI in educational environments.

THEORETICAL IMPLICATIONS

This research contributes to the development of the theory *of Self Regulated Learning* in the context of utilizing artificial intelligence-based technology in mathematics learning. The research findings reinforce Zimmerman's (2002) view that self-regulation skills are a critical factor in determining students' success in managing the learning process independently.

In addition, this study expands the study of the integration of Artificial Intelligence in education by showing that the influence of technology on learning outcomes is not always direct. The research results prove that *Self Regulated Learning* acts as a psychological mechanism that

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explains how the use of generative AI can contribute to the formation of students' learning independence. This finding provides a new perspective that the effectiveness of educational technology needs to be understood not only from the aspect of the technology itself, but also from the psychological factors that influence its use.

PRACTICAL IMPLICATIONS

The research results provide practical implications for teachers, schools, and educational policy makers in integrating generative AI into the learning process.

For teachers, the use of generative AI should not only focus on providing access to information or completing assignments, but also on developing students' self-regulation skills. Teachers can design learning activities that encourage students to set learning goals, monitor their progress, and reflect on their learning outcomes.

For schools, the research findings demonstrate the importance of developing policies for the use of generative AI that are not only oriented towards the use of technology, but also towards developing students' independent learning skills. Schools need to provide adequate digital literacy and mentoring so that students can utilize generative AI responsibly and productively.

For educational policy makers, the results of this study can be a basis for formulating strategies for integrating artificial intelligence into learning that not only emphasize technological aspects, but also strengthen 21st-century learning competencies, especially *Self Regulated Learning* and learning independence.

RESEARCH LIMITATIONS

This study has several limitations that need to be considered in interpreting the research results.

First, the research was only conducted on students of MAN 2 Sinjai so that the research results cannot be generalized widely across all levels of education or different school contexts.

Second, the research uses a survey approach with a cross-sectional design so that the data obtained only describes the condition of respondents in a certain time period. Therefore, the relationships between the variables found need to be understood in the context of the limitations of the research design used.

Third, the study focused solely on the variables of intensity of generative AI use, *Self Regulated Learning* , and learning independence. There are various other factors that could potentially influence student learning independence, such as learning motivation, digital literacy,

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self-efficacy, supportive learning environments, and metacognitive abilities, which were not examined in this study.

SUGGESTIONS FOR FURTHER RESEARCH

Based on the limitations of the research that have been described, further research is recommended to expand the scope of respondents at various levels of education and different regions in order to obtain more representative results.

Future research can also develop the research model by incorporating other variables that have the potential to act as mediators or moderators, such as learning motivation, digital literacy, academic self - *efficacy* , *academic resilience* , and students' metacognitive abilities. Furthermore, the use of a longitudinal research design is recommended to obtain a more comprehensive picture of changes in student learning behavior in utilizing generative AI over time. This way, understanding the role of generative AI in supporting independent learning can be studied in greater depth and sustainably.

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