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Self-Regulated Learning of Junior High School Students and Their Mathematical Problem-Solving Ability in Artificial Intelligence-Based Learning

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Abstract

This study aims to describe students' mathematical problem-solving abilities from the perspective of Self-Regulated Learning (SRL) in Artificial Intelligence (AI)-based learning. The study employed a descriptive quantitative approach involving 36 eighth-grade students. Data were collected through an SRL questionnaire and a mathematical problem-solving test, then analyzed using descriptive statistics, specifically means and percentages. The results show that 27.8% of students have high SRL, 50.0% have moderate SRL, and 22.2% have low SRL. The average mathematical problem-solving ability in the high SRL category was 85.40, in the moderate category 74.20, and in the low category 61.50. The highest indicator was in the ability to understand problems, while the lowest was in checking the results of problem-solving. The research results show that students with high SRL have better mathematical problem-solving skills than students with moderate and low SRL. Therefore, strengthening SRL needs to be a priority in the implementation of AI-based learning to improve students' mathematical problem-solving skills.

INTRODUCTION

Mathematics is one of the subjects that plays a key role in developing logical, critical, creative, and systematic thinking skills (Rachmantika & Wardono, 2019). In the process of learning mathematics, students are not only expected to understand concepts and procedures, but also to be able to apply their knowledge to solve various problems (Nurmilah, 2023). Therefore, mathematical problem-solving skills are one of the key competencies that students must possess. According to the National Council of Teachers of

Mathematics (NCTM, 2000), problem-solving is a primary focus of mathematics education because it helps students develop higher-order thinking skills and apply mathematical concepts in everyday life (Pujiadi & Widyaiswra, 2020).

Mathematical problem-solving skills include the ability to understand a problem, plan a solution strategy, carry out the solution, and evaluate the results obtained (Siswanto & Meiliasari, 2024). This skill is an important indicator of success in learning mathematics because it enables students to handle various situations that require sound reasoning and decision-making (Nun & Suhendri, 2025). However, various research findings indicate that students' mathematical problem-solving skills in Indonesia are still relatively low (Sutra, 2024). Students often have difficulty understanding problems, determining solution strategies, and connecting mathematical concepts to the given context. This situation highlights the need to consider various factors that can influence students' mathematical problem-solving abilities.

One factor believed to influence mathematical problem-solving ability is self-regulated learning (Zeidner & Stoeger, 2019). Self-Regulated Learning is a student's ability to independently manage and control their learning process through planning, monitoring, strategizing, and evaluating their learning outcomes. According to Zimmerman (2002), students with a high level of Self-Regulated Learning tend to be more active, responsible, and capable of using effective learning strategies to complete tasks and solve problems they encounter (Hanifah & Rusmawati, 2019). In mathematics instruction, students with a high level of self-regulated learning are generally able to identify learning difficulties, find solutions independently, and reflect on the process and outcomes of problem-solving (Witaningsih, 2009).

Conversely, students with low levels of Self-Regulated Learning tend to rely on others for help and struggle when faced with problems that require complex reasoning and problem-solving strategies (Titik Kristiyani, 2016). The relationship between self-regulated learning and mathematical problem-solving ability has been extensively studied. Previous studies have shown that students with high levels of self-regulated learning tend to perform better on math problems than students with low levels of self-regulated learning (Fitriani, 2023). Furthermore, a literature review on self-regulated learning found that the ability to independently manage the learning process contributes to improvements in critical thinking skills, motivation to learn, and problem-solving skills. These findings indicate that students' success in solving math problems is influenced not only by cognitive abilities but also by their ability to independently manage the learning process (Montero Panadero, 2017).

Rapid technological advancements have brought about various innovations in the field of education, one of which is the use of Artificial Intelligence (AI) in learning. Artificial Intelligence enables more adaptive, personalized, and interactive learning through real-time feedback, recommendations for learning materials tailored to students' needs, and learning support that is accessible at any time (Amalia, 2024). The use of AI in mathematics education provides students with opportunities to learn independently while also increasing their engagement in the learning process.

Various studies show that the use of Artificial Intelligence in mathematics education can help improve students' motivation to learn, conceptual understanding, and critical thinking and problem-solving skills. Researchers have found that AI-based learning can increase student engagement, provide rapid feedback, and help students gain a deeper understanding of mathematical concepts through learning tailored to individual needs (Azhari, 2025). These findings are supported by the results of a systematic review conducted by other researchers, which show that the application of Artificial Intelligence in mathematics education has a positive impact on improving students' critical thinking skills, problem-solving abilities, and independent learning. AI is also capable of creating a more personalized learning experience, allowing students to learn according to their individual abilities and learning pace (Yunita & Gunawan, 2025).

Although various studies have examined self-regulated learning and the use of artificial intelligence in mathematics education, most of these studies still focus on the impact of each variable on students' learning outcomes or academic achievement (Fanni Yunita, 2025). Research specifically examining junior high school students' mathematical problem-solving abilities from the perspective of self-regulated learning in the context of Artificial Intelligence-based learning remains relatively limited. However, the combination of self-regulation skills and an AI-supported learning environment has the potential to provide a more comprehensive understanding of the factors that influence students' success in solving mathematical problems.

Advances in digital technology have introduced Artificial Intelligence (AI) as an innovation in mathematics education. Artificial Intelligence (AI) enables more adaptive learning through automated feedback, personalized content recommendations based on students' needs, and exercises tailored to individual abilities. This approach provides students with opportunities to learn more independently and develop higher-order thinking skills, including mathematical problem-solving abilities. In mathematics education, Artificial Intelligence (AI) can provide adaptive exercises tailored to students' ability levels, offer immediate feedback, and help students understand concepts through material recommendations that align with their learning needs. This approach allows students to learn at their own pace and according to their individual characteristics, thereby enhancing engagement and independence in learning.

From the perspective of Self-Regulated Learning (SRL), learning success is determined not only by cognitive abilities, but also by students' ability to regulate their own learning process. Zimmerman (2002) explains that SRL consists of three main phases: forethought (planning), performance (monitoring and self-regulation), and self-reflection (self-evaluation). These three phases play a crucial role in helping students understand problems, select problem-solving strategies, monitor their work process, and evaluate the results they obtain. In the planning phase, students set learning goals and determine the strategies they will use. In the performance phase, students monitor their learning progress and regulate their learning behavior. Finally, in the reflection phase, students evaluate the results obtained to improve their future learning processes.

Various studies show that SRL is positively correlated with academic achievement and mathematical problem-solving skills. Other studies have also found that the use of AI can increase student engagement, provide rapid feedback, and support more personalized learning. However, most studies still examine SRL and Artificial Intelligence (AI) separately, or focus on general learning outcomes. Research that specifically analyzes students' mathematical problem-solving abilities based on their level of Self-Regulated Learning in AI-based learning environments, particularly at the junior high school level, remains limited.

Based on the above discussion, it is important to examine junior high school students' mathematical problem-solving abilities from the perspective of self-regulated learning in Artificial Intelligence-based learning. This study is expected to provide an overview of students' mathematical problem-solving abilities at various levels of self-regulated learning in an AI-based learning environment, while also serving as a foundation for the development of more effective and adaptive mathematics learning strategies that meet the demands of educational technology advancements in the digital age.

RESEARCH METHODOLOGY

This study uses a quantitative approach with a descriptive method (Syahputri, 2023) to describe junior high school students' mathematical problem-solving abilities from the perspective of self-regulated learning in Artificial Intelligence (AI)-based instruction. The study was conducted with eighth-grade junior high school students who had participated in AI-based instruction. The research sample was selected using purposive sampling in accordance with the study's objectives (Yustia Putri, 2017).

The study population consisted of all 375 eighth-grade junior high school students. The study sample consisted of 36 students selected using purposive sampling. This technique was used because the study required subjects who had experience learning using an Artificial Intelligence platform so that they could provide data relevant to the research objectives. The sample selection criteria included: (1) active eighth-grade students, (2) students who had participated in Artificial Intelligence-based mathematics learning, and (3) students willing to serve as research respondents. The sample consisted of 3 male students and 3 female students aged 13–14 years.

The instruments used consisted of a Self-Regulated Learning questionnaire and a mathematical problem-solving ability test. The Self-Regulated Learning questionnaire was developed based on Zimmerman's indicators, which include planning, self-regulation, monitoring, and self-reflection (Rohmad & Sarah, 2021). The mathematical problem-solving test is structured according to Polya's problem-solving steps: understanding the problem, formulating a plan, implementing the plan, and checking the solution. (Syahla Kamila & Galih Adirakasiwi, 2021).

Data were collected by distributing questionnaires and administering tests to students. The data were then analyzed using descriptive statistics, grouping students into high, moderate, and low Self-Regulated Learning categories. The results of the analysis are presented in the form of means, percentages, tables, and descriptive analyses to provide an overview of students' mathematical problem-solving abilities based on their level of Self-Regulated Learning in Artificial Intelligence-based learning.

RESEARCH RESULTS

This study aims to describe junior high school students' mathematical problem-solving abilities in terms of their levels of self-regulated learning in Artificial Intelligence (AI)-based instruction. Based on the results of the self-regulated learning questionnaire, students were grouped into three categories: high, moderate, and low levels of self-regulated learning.

Tabel 1.
Student Self-Regulated Learning Category

No	Category: Self-Regulated Learning	Number of Students	Percentage
1	High	10	27,8%
2	Medium	18	50,0%
3	Low	8	22,2%
	Total	**36**	**100%**

Based on Table 1, the majority of students fall into the moderate Self-Regulated Learning category, accounting for 50.0%. Meanwhile, 27.8% of students fall into the high Self-Regulated Learning category, and 22.2% fall into the low Self-Regulated Learning category. Next, an analysis was conducted of the students' mathematical problem-solving abilities based on their Self-Regulated Learning categories.

Tabel 2.
Average Mathematical Problem-Solving Ability by Self-Regulated Learning Category

No	Category: *Self-Regulated Learning*	Rata-rata Nilai
1	High	85,40
2	Medium	74,20
3	Low	61,50

The data in Table 2 show that students with high levels of self-regulated learning achieved a higher average score on mathematical problem-solving skills compared to students with moderate or low levels of self-regulated learning. Students in the high Self-Regulated Learning category scored an average of 85.40, while those in the moderate category scored an average of 74.20 and those in the low category scored an average of 61.50. Further analysis was conducted on each indicator of mathematical problem-solving ability based on Polya's steps.

Tabel 3.
Percentage of Achievement for the Mathematical Problem-Solving Skills Indicator

No	Indikator	***Self-Regulated Learning* Tinggi**	***Self-Regulated Learning* Sedang**	***Self-Regulated Learning* Rendah**
1	Understanding the problem	92%	84%	71%
2	Developing a plan	88%	76%	63%
3	Implementing the plan	86%	72%	58%
4	Reviewing the plan	79%	65%	47%

Table 3 shows that the indicator with the highest achievement across all categories is "understanding the problem." Conversely, the indicator "reviewing the solution" had the lowest achievement. Students with high levels of self-regulated learning performed better on all indicators compared to the other groups.

The results of the study show that students with high levels of self-regulated learning tend to have better mathematical problem-solving skills than students with moderate or low levels of self-regulated learning. These findings indicate that the ability to manage the learning process independently plays an important role in helping students understand and solve mathematical problems.

Students with high levels of self-regulated learning demonstrate strong abilities in the problem-understanding stage. They are able to identify known information and the information being asked for in a problem in a more systematic manner. In addition, students in this group are able to determine appropriate problem-solving strategies before performing calculations. These characteristics indicate a well-developed learning planning process, which is one of the key indicators of self-regulated learning.

When formulating a solution plan, students with high levels of self-regulated learning appear better able to select relevant concepts and formulas to use. They do not merely rely on memorizing procedures, but also strive to understand the relationships among the mathematical concepts needed to solve problems. In contrast, students with low levels of

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self-regulated learning tend to have difficulty determining the appropriate strategy and thus often make mistakes early on in the problem-solving process.

The research findings also show that students with high levels of self-regulated learning are better able to carry out their problem-solving plans. They are able to follow planned steps systematically and perform calculations more carefully. Meanwhile, students with low levels of self-regulated learning often make mistakes in the calculation process and in applying mathematical concepts. This indicates that the ability to control and monitor the learning process influences students' success in solving mathematical problems.

A fairly striking difference was observed in the indicator of reviewing completed work. Most students with high levels of self-regulated learning review their answers before finishing the problem-solving process. In contrast, students with low levels of self-regulated learning tend to write down their final answers immediately without evaluating either the process or the results. This suggests that self-reflection a component of self-regulated learning plays a crucial role in improving the quality of mathematical problem-solving.

The results of the study show that students' mathematical problem-solving abilities differ across each category of Self-Regulated Learning. Based on the results of the Self-Regulated Learning questionnaire, students were grouped into high, moderate, and low categories. The analysis revealed that students in the high Self-Regulated Learning category had better average mathematical problem-solving skills than those in the moderate and low categories. These findings indicate that students' level of self-regulation contributes to their success in solving mathematical problems in Artificial Intelligence (AI)-based learning.

This study shows that the use of Artificial Intelligence (AI) provides students with the opportunity to receive quick and personalized feedback. Students can identify mistakes made during the learning process and receive recommendations for improvement tailored to their individual needs. This helps students develop self-regulation skills and encourages them to be more active in the learning process. AI-based learning also allows students to learn at their own pace and according to their individual abilities. However, the study's findings indicate that the effectiveness of AI is not solely determined by the sophistication of the technology used but is also influenced by students' ability to manage their own learning process independently.

According to Zimmerman (2002), self-regulated learning comprises three main phases: the forethought phase (planning), the performance phase (execution and monitoring), and the self-reflection phase (reflection and self-evaluation). These three phases are used to analyze how students manage the learning process and solve math problems in an Artificial Intelligence-based learning environment.

When formulating a solution plan, students with high levels of self-regulated learning tend to find it easier to determine the appropriate strategy. They are able to select relevant concepts and procedures based on the characteristics of the problem at hand. In addition, students in this category appear more confident in determining solution steps and are less likely to rely on help from others. These findings indicate that students possess strong learning planning skills, enabling them to utilize Artificial Intelligence features such as content recommendations and adaptive exercises to support their thinking processes.

When carrying out a problem-solving plan, students with high levels of self-regulated learning are able to control the problem-solving process more systematically. They can monitor each step they take and immediately correct any errors they find. Research findings indicate that students in this category rarely make procedural errors because they are accustomed to monitoring the ongoing problem-solving process. This aligns with the "performance" phase in Zimmerman's theory, which emphasizes the importance of self-control and monitoring of current learning activities.

When reviewing their solutions, students with high levels of self-regulated learning demonstrated better reflective abilities than the other groups. They not only checked the final results but also reviewed the procedures they used to ensure that all steps had been carried out correctly. These reflective abilities indicate that the students were able to evaluate their learning outcomes. From Zimmerman's perspective, this condition falls under the self-reflection phase that is, an individual's ability to evaluate learning processes and outcomes as a basis for improvement in subsequent learning activities.

Unlike students in the high Self-Regulated Learning category, students in the moderate Self-Regulated Learning category demonstrated fairly good problem-solving skills, but were not yet consistent across all indicators. Some students are able to understand problems and formulate solution plans well, but still have difficulty evaluating the results they obtain. They tend to focus on arriving at the final answer without double-checking the process they have followed. This indicates that their monitoring and self-reflection skills have not yet developed optimally.

Meanwhile, students with low levels of self-regulated learning demonstrated relatively lower mathematical problem-solving abilities compared to the other groups. The difficulties they experienced were not limited to the stages of planning and executing solutions, but also extended to the stage of understanding the problem. Some students struggled to identify the key information in the problem, causing their problem-solving process to lack direction. They also tended to attempt to solve problems directly without first developing a thorough plan.

The low problem-solving ability observed in the low Self-Regulated Learning group indicates that the ability to regulate the learning process plays a crucial role in the success of mathematics learning. Although Artificial Intelligence-based learning has provided various supportive features such as automatic feedback, content recommendations, and adaptive exercises, students with low self-regulation skills have not been able to make optimal use of these features. They tend to wait for instructions from teachers or rely on help from others when facing difficulties. These findings suggest that the presence of technology does not automatically improve students' learning abilities if it is not balanced by adequate self-regulation skills. Zimmerman states that self-regulated learning is an active process that involves an individual's ability to plan, monitor, and evaluate learning activities to achieve specific goals. Students with a high level of self-regulation tend to be better able to utilize available learning resources, including artificial intelligence technology, to support the achievement of optimal learning outcomes. Conversely, students with low self-regulation tend to have difficulty making the most of the various learning resources that have been provided.

DISCUSSION

The findings of this study regarding students' mathematical problem-solving abilities in Artificial Intelligence-based learning are consistent with Zimmerman's theory, which states that students with high levels of self-regulated learning tend to be able to set learning goals, monitor their learning progress, and evaluate their results independently. These abilities help students tackle tasks that require complex reasoning and problem-solving.

Based on the results of the mathematical problem-solving ability test administered to students after participating in Artificial Intelligence (AI)-based learning, it was found that students' mathematical problem-solving abilities fell into varying categories. In general, most students were able to understand the problems presented and identify both the given information and the information being asked for in the questions. However, some students still struggled with formulating solution strategies and evaluating their answers.

Regarding the "understanding the problem" indicator, most students were able to identify known information, determine what was being asked, and sort out relevant information from the given problem. The high achievement on this indicator shows that students already have a good initial understanding of mathematical problems. The ability to understand problems is a key foundation in the problem-solving process because success in subsequent stages is heavily influenced by students' accuracy in interpreting problems. Thus, students' performance on this indicator can be categorized as fairly good because they are able to construct an initial representation of the problems they face.

Furthermore, regarding the indicator of formulating a solution plan, differences in ability among students began to emerge. Some students were able to determine strategies appropriate to the characteristics of the problem and relate them to the mathematical concepts they had learned. However, others still struggled to choose the right procedure to solve the problem. This situation indicates that students' mastery of mathematical concepts has not yet been fully accompanied by strategic thinking skills. These difficulties primarily arise in problems that require more complex reasoning or present a context different from the examples typically provided in class. These findings suggest that students still tend to rely on routine solution patterns and have not yet fully developed the ability to devise problem-solving strategies independently.

Regarding the indicator of implementing a problem-solving plan, most students were able to follow the planned steps. However, various procedural errors and calculation errors were still found that affected the accuracy of the final answers. These findings indicate that students have actually understood the concepts and strategies to be used but have not yet fully developed the necessary precision and operational skills in the problem-solving process. These errors may be caused by a lack of practice, rushing to complete the problems, or poor concentration while performing calculations. Therefore, students' ability to implement a problem-solving plan still needs to be strengthened through instruction that provides them with more opportunities to practice solving a variety of problem types.

Meanwhile, the indicator for reviewing work results showed the lowest achievement. Most students did not double-check either the process or the results they had obtained. They tended to assume that their answers were correct without further verification. The low achievement on this indicator suggests that students' metacognitive skills particularly in monitoring and evaluating their own work have not yet developed optimally. In fact, reviewing work is crucial for identifying procedural errors or calculation mistakes that may have occurred during the problem-solving process. These findings indicate the need for learning strategies that foster habits of reflection and self-evaluation so that students become more thorough and critical of their work.

In addition, AI-based learning allows students to have a more personalized learning experience. Each student can access materials and exercises tailored to their skill level. This enables students to learn independently and develop more effective problem-solving strategies. Thus, AI-based learning serves not only as a learning tool but also as a means of supporting the development of students' higher-order thinking skills.

The findings of this study are consistent with the research by Hwang and Tu, which states that artificial intelligence can increase student engagement in the learning process and help improve problem-solving skills by providing quick and accurate feedback. In addition, the results of a systematic review conducted by Song, Nor, and Alias indicate that the application of artificial intelligence in mathematics education can enhance students' critical thinking and problem-solving skills through a more adaptive and personalized learning process.

The results of this study show that the use of artificial intelligence in learning has a positive impact on students' mathematical problem-solving skills. Through features such as automatic feedback, adaptive practice problems, and learning recommendations tailored to students' needs, artificial intelligence helps students gain a deeper understanding of mathematical concepts. Students can immediately identify their mistakes, allowing them to correct them more quickly than with conventional learning methods.

Meanwhile, the findings of this study on students' mathematical problem-solving abilities as viewed through the lens of self-regulated learning in artificial intelligence-based learning are also consistent with Panadero's (2017) research, which explains that students with high levels of self-regulated learning are better able to control the learning process, select problem-solving strategies, and evaluate the results obtained. Furthermore, the findings of Hwang and Tu (2021) indicate that the use of artificial intelligence in learning can enhance problem-solving skills when students are actively engaged in the learning process. Thus, the success of implementing artificial intelligence in mathematics education is not determined solely by the technology used.

The better students' self-regulated learning skills are, the better their mathematical problem-solving abilities will be in Artificial Intelligence-based learning. Therefore, teachers need to develop learning strategies that focus not only on mastery of mathematical content but also on strengthening students' self-regulation skills through activities such as learning planning, monitoring the learning process, and reflecting on learning outcomes. In this way, the use of Artificial Intelligence in learning can yield more optimal results in improving students' mathematical problem-solving skills.

The results of the study show that students with high levels of self-regulated learning demonstrate better mathematical problem-solving skills than students in the moderate or low categories. During the problem-understanding stage, students with high levels of self-regulated learning were able to identify important information in the problem completely and systematically. They could distinguish between known information and what was being asked and were able to connect this information to build an understanding of the given problem. When analyzed using Zimmerman's theory, this ability indicates a well-developed "forethought" phase the ability to plan and set goals before beginning to solve a problem.

SIMPULAN

Based on the results of the above study, it can be concluded that students' mathematical problem-solving abilities in Artificial Intelligence (AI)-based learning are influenced by their level of Self-Regulated Learning (SRL). Of the 36 students, 27.8% fell into the high SRL category, 50.0% into the moderate category, and 22.2% into the low category. Students with high SRL achieved the highest average mathematical problem-solving ability (85.40), followed by those in the moderate category (74.20) and the low category (61.50). When examined by problem-solving indicators, the highest achievement was found in the "understanding the problem" indicator, while the lowest achievement was found in the "checking the solution" indicator. This indicates that students are generally able to understand the problems presented but still lack the ability to reflect on and evaluate their answers. Additionally, Artificial Intelligence-based learning contributes positively to mathematical problem-solving skills through rapid feedback, adaptive practice, and a more personalized learning experience. Thus, the higher a student's level of Self-Regulated Learning, the better their mathematical problem-solving skills demonstrated in Artificial Intelligence-based learning.

Students with high levels of Self-Regulated Learning (SRL) demonstrate better mathematical problem-solving skills than those with moderate or low levels of SRL. These findings indicate that the ability to regulate, monitor, and evaluate the learning process plays a crucial role in students' success in solving mathematical problems. Artificial Intelligence (AI)-based learning provides support through rapid feedback, adaptive practice, and learning recommendations tailored to students' needs. However, the effectiveness of AI is greatly influenced by students' self-regulation abilities. Students with high SRL are better able to plan, monitor, and evaluate their learning processes, allowing them to make optimal use of AI technology. Conversely, students with low SRL tend to have difficulty understanding problems, determining solution strategies, and evaluating their results.

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