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The influence of GeoGebra-assisted flipped classroom learning model on mathematical problem-solving abilities and self-regulated learning of junior high school students

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Abstract: This study aims to determine the effect of the GeoGebra-assisted flipped classroom learning model on the mathematical problem-solving abilities and self-regulated learning of junior high school students. This research employed a quasi-experimental design with a Pretest-Posttest Control Group Design. The study was conducted at SMP Negeri 1 Ngemplak, involving grade IX students selected through simple random sampling. Data collection utilized a problem-solving ability test and a self-regulated learning questionnaire, which were analyzed using the Independent Samples t-test at a significance level of 0.05. The results showed that: (1) There is a positive and significant influence of the GeoGebra-assisted flipped classroom model on students' mathematical problem-solving abilities (Sig. 0.001 < 0.05); (2) There is no significant influence of the model on students' self-regulated learning (Sig. 0.834 > 0.05). Detailed analysis reveals that while the model effectively enhances cognitive skills through dynamic visualization and active problem-solving, it has not significantly impacted affective aspects due to the short duration of implementation and the cognitive load associated with adapting to new technology.

Keywords:
Flipped Classroom, GeoGebra, Mathematical Problem-Solving Ability, Self-Regulated Learning

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1. Introduction

The rapid advancement of technology and information in the era of globalization has fundamentally transformed the landscape of human life, changing how people learn, work, and interact (Lyapina et al., 2019). Education, as a cornerstone of human development, is required to adapt to these changes to remain relevant. Kemendikbudristek (2022) emphasizes the urgency of learning transformation to develop 21st-century competencies, which include critical thinking, creativity, communication, and collaboration skills. Consequently, innovation in instructional practices is essential to shape students who possess not only subject matter mastery but also the essential life skills needed to navigate the challenges of the 21st century.

Mathematics education plays a pivotal role in fostering these skills, particularly the ability to solve problems. Mathematical problem-solving ability refers to a student's capacity to find solutions or answers to encountered problems by integrating various concepts and procedures (Nugroho et al., 2025; Ulya et al., 2024). This ability is intrinsically linked to the processes of reasoning, selecting appropriate strategies, and formulating logical solution steps (Chen et al., 2020; Suparman et al., 2021). Furthermore, mathematical problem-solving skills are applicable in daily life, preparing individuals to face future complexities (Maulinisa, 2023).

However, empirical evidence suggests that students' mathematical problem-solving abilities remain suboptimal. According to the PISA 2022 results, Indonesian students' mathematical literacy ranks 70th out of 81 countries with an average score of 366, significantly below the OECD average. This low achievement is closely associated with a lack of instructional variety, where teachers predominantly utilize conventional methods (Nugroho et al., 2025). In many classrooms, teacher-centered approaches such as monotonous lectures are prevalent, providing limited opportunities for students to engage in challenging problem-solving tasks (Nugroho, 2025; Nugroho et al., 2025; Nugroho & Septianisha, 2025). These practices restrict students' active roles and limit their access to diverse learning resources (Vera et al., 2021).

In addition to cognitive factors, the low mathematical problem-solving ability of students is also correlated with their level of self-regulated learning (SRL). Self-regulated learning is defined as the ability of students to participate actively in their learning process through metacognitive, motivational, and behavioral engagement (Schunk & Zimmerman, 1994; Zimmerman, 2010). A high level of SRL is crucial for students to take initiative, determine learning strategies, and overcome obstacles. However, field observations indicate that students' SRL is often low (Daumiller & Dresel, 2019; Nurdin et al., 2023; Tee et al., 2021), characterized by a lack of motivation, indiscipline, and negligence in completing school assignments (Atmojo et al., 2023; Barkhorn et al., 2025; Lei et al., 2022).

To address these cognitive and affective issues, an innovative learning model is required. The Flipped Classroom model offers a potential solution by reversing the traditional learning process. In this model, students study instructional materials independently at home (pre-class phase), thereby maximizing class time for interactive problem-solving activities (Rohmatulloh & Nindiasari, 2022). To further enhance this model, the integration of technology such as GeoGebra is proposed. GeoGebra is a dynamic mathematics software that excels in visualizing abstract mathematical concepts (Aien et al., 2025). The integration of GeoGebra has been shown to be effective in improving critical thinking and problem-solving skills (Widyastuti et al., 2018).

Previous research indicates that Flipped Classroom and GeoGebra, when applied separately or in combination, can improve learning outcomes. (Hasibuan et al., 2022) demonstrated that GeoGebra supports the improvement of problem-solving skills and self-regulated learning. Similarly, Auliza & Widyastuti (2024) and Sari et al. (2020) found that the Flipped Classroom positively impacts both variables. However, research combining both the Flipped Classroom and GeoGebra specifically at the junior high school level remains limited. Therefore, this study aims to investigate the effect of the GeoGebra-assisted flipped classroom learning model on the mathematical problem-solving abilities and self-regulated learning of junior high school students.

2. Methods

This study employed a quantitative approach with a quasi-experimental design, specifically the Pretest-Posttest Control Group Design. This design was chosen to compare the outcomes between a group receiving the specific treatment and a control group, while controlling for initial differences through pre-tests. The population of the study comprised all grade IX students of SMP Negeri 1 Ngemplak in the 2025/2026 academic year. The sampling technique used was simple random sampling, which resulted in the selection of class IX D as the experimental group (32 students) and class IX B as the control group (32 students). The experimental class was taught using the GeoGebra-assisted flipped classroom model, where students accessed video materials and GeoGebra simulations before class and engaged in active problem-solving during class. The control class was taught using the conventional expository model.

Data collection utilized two primary instruments: a test and a questionnaire. Mathematical problem-solving ability was measured using a descriptive test consisting of 5 essay questions based on Polya's problem-solving indicators. Self-regulated learning was measured using a questionnaire consisting of 20 statements covering metacognitive, motivational, and behavioral aspects. Both instruments underwent validity testing using expert judgment and reliability testing using Cronbach's Alpha formula to ensure the data's accuracy and consistency. The collected data were analyzed using descriptive and inferential statistics. Descriptive analysis provided an overview of the mean scores and standard deviations. Prerequisite tests included the Normality Test (Shapiro-Wilk) and Homogeneity Test (Levene's Test). To ensure that both groups started at a comparable level, an Initial Ability Similarity Test was conducted on the pre-test and initial questionnaire data. The hypothesis testing was performed using the Independent Samples t-test with the assistance of SPSS software at a significance level of 0.05.

3. Results and Discussion

The research data were obtained from the pre-test and post-test of mathematical problem-solving abilities and the initial and final questionnaires of self-regulated learning. Descriptive analysis revealed that the average post-test score for problem-solving ability in the experimental class was 73.56, which is higher than the control class average of 56.63. Conversely, for self-regulated learning, the average final score of the experimental class (60.81) was relatively similar to that of the control class (60.47).

Before conducting hypothesis testing, prerequisite tests were performed. The normality test results are presented in Table 1. As shown in Table 1, the significance values (Sig.) for the pre-test and post-test of problem-solving abilities, as well as the initial and final questionnaires for self-regulated learning in both classes, are all greater than 0.05. This indicates that the data are normally distributed. Consequently, parametric statistics can be used for further analysis. Following the normality test, a homogeneity test was conducted to determine if the variances of the two groups were equal. The results are shown in Table 2.

Table 1. Normality Test Results

Variable	Data Type	Class	Sig. value	Interpretation
Mathematical Problem-Solving Ability	Pre-test	Experimental	0.662	Normal
		Control	0.085	Normal
	Post-test	Experimental	0.156	Normal
		Control	0.117	Normal
Self-Regulated Learning	Initial Questionnaire	Experimental	0.545	Normal
		Control	0.069	Normal
	Final Questionnaire	Experimental	0.289	Normal
		Control	0.222	Normal

Table 2. Homogeneity Test Results

Variable	Data Type	Sig. (Levene)	Interpretation
Mathematical Problem-Solving Ability	Pre-test	0.734	Homogeneous
	Post-test	0.152	Homogeneous
Self-Regulated Learning	Initial Questionnaire	0.618	Homogeneous
	Final Questionnaire	0.761	Homogeneous

Table 2 displays the results of Levene's Test for Equality of Variances. The significance values for all variables are greater than 0.05 (Problem Solving Pre-test: 0.734; Post-test: 0.152; SRL Initial: 0.618; Final: 0.761). These results confirm that the variance between the experimental and control classes is homogeneous, fulfilling the second prerequisite for the t-test. To ensure that any difference in the results was due to the treatment and not initial differences, an initial ability similarity test was conducted.

Table 3. Initial Ability Similarity Test Results

Variable	Data Type	Sig. (2-tailed)	Interpretation
Mathematical Problem-Solving Ability	Pre-test	0.321	No significant difference
Self-Regulated Learning	Initial Questionnaire	0.570	No significant difference

Table 3 shows the Independent Samples t-test results for the initial data. The Sig. (2-tailed) values for mathematical problem-solving ability (0.321) and self-regulated learning (0.570) are both greater than 0.05. This implies that there was no significant difference in the initial abilities of the students in the experimental and control classes before the treatment began.

The main hypothesis testing was then conducted to determine the effect of the treatment. The results for mathematical problem-solving ability are presented in Table 4.

Table 4. Hypothesis Test for Mathematical Problem-Solving Ability

Variable	t	df	Sig. (2-tailed)	Interpretation
Mathematical Problem-Solving Ability	3.475	62	0.001	Significant difference

Based on Table 4, the t-test analysis yielded a t-value of 3.475 with a Sig. (2-tailed) value of 0.001. Since 0.001 < 0.05, the null hypothesis is rejected. This indicates that there is a significant difference in mathematical problem-solving abilities between students taught with the GeoGebra-assisted flipped classroom model and those taught with the expository model.

To provide deeper insight into the improvement in problem-solving skills, Figure 1 compares post-test scores across Polya's four indicators: understanding the problem, devising a plan, carrying out the plan, and looking back.

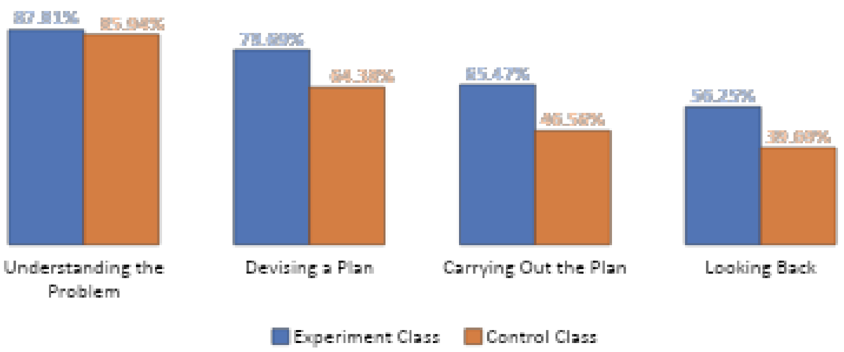

Figure 1. Comparison of Average Post-test Scores per Problem-Solving Indicator

As visualized in Figure 1, the experimental class consistently outperformed the control class across all four problem-solving indicators. First, during the problem-understanding stage, the difference between the two classes was relatively small. This suggests that the flipped classroom strategy, which requires students to study material independently before class, effectively prepares them to grasp the context of problems, similar to teacher explanations in conventional settings. This finding aligns with (Supriatna, 2021), who posits that pre-class activities in flipped classrooms are crucial for building initial understanding. Additionally, the use of GeoGebra aids this process by providing interactive visualizations that make abstract concepts more accessible (Aien et al., 2025).

A more distinct advantage was observed in the second indicator, devising a plan. The experimental class demonstrated a superior ability to formulate structured strategies. This improvement is attributed to GeoGebra's interactive nature, which allows students to visualize relationships among mathematical objects, thereby facilitating the identification of appropriate solution paths. This supports the findings of (Nugroho, 2024; Nugroho et al., 2025; Nugroho & Septianisha, 2025), who argue that GeoGebra helps students perceive connections between objects and understand concepts concretely and intuitively.

The most significant improvement occurred in the carrying out the plan indicator. This is likely due to the shift in class time allocation; the flipped classroom model maximizes face-to-face sessions for active problem-solving rather than passive listening (Abeysekera & Dawson, 2015). Furthermore, GeoGebra's feature that integrates algebraic and geometric views (Hohenwarter et al., 2008) allows students to test their conjectures and execute calculation steps with immediate visual feedback, resulting in more directed and error-free procedures.

Finally, in the looking back phase, students in the experimental group showed better proficiency in verifying their answers and drawing accurate conclusions. The dynamic visualization capabilities of GeoGebra enabled students to cross-check their calculation results with the visual representation, ensuring consistency. As noted by (Rahmadia et al., 2024), clear visual representations foster a stronger conceptual understanding, which is essential for evaluating the reasonableness of a solution and formulating precise conclusions.

In contrast to the cognitive results, the hypothesis test for self-regulated learning showed different results, as seen in Table 5.

Table 5. Hypothesis Test for Self-Regulated Learning

Variable	t	df	Sig. (2-tailed)	Interpretation
Mathematical Problem-Solving Ability	3.475	62	0.001	Significant difference

Table 5 shows a Sig. (2-tailed) value of 0.834, which is greater than 0.05. This means there is no significant difference in self-regulated learning between the two groups. Although the experimental class score was slightly higher, statistically, the treatment did not produce a significant impact on students' independence. The lack of significant improvement in self-regulated learning in this study contrasts with previous findings by (Auliza & Widyastuti, 2024) and (Sari et al., 2020), who reported positive impacts of the flipped classroom on student independence. This discrepancy warrants a critical examination based on three key factors.

First, regarding duration: unlike cognitive skills which can be improved through intensive drilling, self-regulated learning is a habit formation process that requires a longer duration to develop. This aligns with (Zimmerman, 1989), who states that personal changes occur through a continuous reciprocal process, not instantly. The study's short duration of only three meetings was likely insufficient to permanently alter students' established study structures.

Second, regarding environmental adaptation: the simultaneous introduction of GeoGebra and the Flipped Classroom format likely imposed a high extrinsic cognitive load. Students had to adapt to a new software interface and a new learning culture. As noted by (Zimmerman, 1989), environmental factors and behavior influence each other; the initial struggle to adapt to the new environment might have overshadowed the formation of self-regulation strategies in the short term.

Third, regarding self-observation bias: the result may be influenced by the accuracy of students' self-assessment. According to (Zimmerman, 1989), successful self-regulation depends on accurate self-observation. Junior high school students, who are still in the developmental stage, may not yet possess high accuracy in assessing their own learning independence, potentially leading to questionnaire scores that do not fully reflect actual behavioral changes.

4. Conclusion

Based on the analysis and discussion, two main conclusions are drawn. First, the GeoGebra-assisted flipped classroom learning model has a positive and significant effect on the mathematical problem-solving abilities of junior high school students. The model proves effective in enhancing specific problem-solving indicators, particularly in devising and carrying out solution plans, aided by dynamic visualization. Second, the model does not have a significant influence on students' self-regulated learning within the constraints of this study. The development of self-regulated learning appears to require a longer intervention period and a gradual introduction of new technologies to minimize cognitive load. Future research is recommended to extend the treatment duration to better capture the development of affective domains.

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