THE IMPACT OF GEOGEBRA INTEGRATION INTO PROBLEM-BASED LEARNING ON MATHEMATICS LEARNING OUTCOMES BASED ON STUDENTS' LEARNING INTEREST

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ABSTRACT This study aimed to examine how the integration of GeoGebra in problem-based learning influences mathematics learning outcomes, taking into account students' learning interest. The study was motivated by low student achievement and the limited use of technological innovation in mathematics instruction. A quasi-experimental method with a Post-Test Only Control Group Design was employed, using a quantitative approach. The participants were 9th-grade students at SMP Muhammadiyah 5 Surakarta. Two classes were selected through cluster random sampling to represent the overall 9th-grade population. The sample consisted of class IX-C, which served as the control group and received PBL without GeoGebra, and class IX-D, which served as the experimental group and received PBL integrated with GeoGebra. The research instruments included a learning interest questionnaire and a mathematics learning outcome test. Data were collected through a post-test and a questionnaire using a 4-point Likert scale. A two-way analysis of variance (ANOVA) with a 2×2 factorial design was used for data analysis. The findings indicated that: (1) the integration of GeoGebra into the PBL model had a significant effect on students' mathematics learning outcomes; (2) students' learning interest significantly influenced their learning outcomes; and (3) there was no significant interaction effect between the learning model and learning interest. These results suggest that applying PBL with GeoGebra is an effective instructional innovation in mathematics teaching, particularly for the topic of Similarity, and that the integration of GeoGebra can enhance students' mathematics learning outcomes.

Keywords: GeoGebra, problem-based learning, learning interest, mathematics learning outcomes

ABSTRAK Penelitian ini bertujuan untuk mengkaji bagaimana integrasi GeoGebra dalam pembelajaran berbasis masalah (Problem-Based Learning/PBL) memengaruhi hasil belajar matematika, dengan mempertimbangkan minat belajar siswa. Penelitian ini dilatarbelakangi oleh rendahnya capaian belajar siswa serta terbatasnya inovasi teknologi dalam pembelajaran matematika. Metode yang digunakan adalah kuasi-eksperimen dengan desain *Post-Test Only Control Group*, menggunakan pendekatan kuantitatif. Partisipan dalam penelitian ini adalah siswa kelas IX SMP Muhammadiyah 5 Surakarta. Dua kelas dipilih melalui teknik *cluster random sampling* untuk mewakili populasi siswa kelas IX secara keseluruhan. Sampel terdiri dari kelas IX-C sebagai kelompok kontrol yang menerima PBL tanpa GeoGebra, dan kelas IX-D sebagai kelompok eksperimen yang menerima PBL dengan integrasi GeoGebra. Instrumen penelitian meliputi angket minat belajar dan tes hasil belajar matematika. Data dikumpulkan melalui tes akhir (*post-test*) dan angket menggunakan skala Likert 4 poin. Analisis data dilakukan dengan analisis varians dua arah (ANOVA) menggunakan desain faktorial 2×2. Hasil penelitian menunjukkan bahwa: (1) integrasi GeoGebra ke dalam model PBL memberikan pengaruh signifikan terhadap hasil belajar matematika siswa; (2) minat belajar siswa berpengaruh signifikan terhadap hasil belajarnya; dan (3) tidak terdapat pengaruh interaksi yang signifikan antara model pembelajaran dan minat belajar. Temuan ini menunjukkan bahwa penerapan PBL dengan GeoGebra merupakan inovasi pembelajaran yang efektif dalam pengajaran matematika, khususnya pada topik Kesebangunan, serta bahwa integrasi GeoGebra dapat meningkatkan hasil belajar matematika siswa.

Kata-kata kunci: GeoGebra, pembelajaran berbasis masalah, minat belajar, hasil belajar matematika

INTRODUCTION

Education plays a crucial role in developing superior and competitive human resources. According to Law Number 20 of 2003 on the National Education System, the objective of education is to optimize individuals' abilities in the intellectual, emotional and social domains. One way to achieve this goal is through mathematics education, which is essential for developing logical, analytical, methodical, and creative thinking patterns that support the advancement of modern science and technology (Nurhandita et al., 2021). As a fundamental discipline, mathematics helps students develop analytical thinking skills that are vital for everyday life. It is a lifelong learning subject that is deeply integrated into human life and continuously relevant (Pramudita et al., 2020). Therefore, students must acquire mathematical skills to solve various problems. With a solid understanding of mathematics, students can more easily adapt to changes and improve their problem-solving abilities, which are beneficial in various aspects of life.

However, in reality, Indonesian students' mathematics achievement remains at a low level based on the 2022 Programme for International Student Assessment (PISA) conducted by the OECD. The mathematics score of Indonesian students declined from 379 in 2018 to 366 in 2022. In comparison, Indonesia's ranking slightly improved from 73rd out of 79 countries in 2018 to 70th out of 81 countries in 2022 (OECD, 2023). This shows that although the ranking improved, the actual performance declined. This result is in agreement with the research carried out by Aidah et al. (2025), which reported that at SMP N 1 Banyudono, only 9% of students achieved high mathematics scores, 24% fell into the medium category, and the majority, 67%, were classified in the low category. A similar condition was observed in the field, particularly at SMP Muhammadiyah 5 Surakarta, the research site. Based on the mathematics test results of ninth-grade students, the average score achieved was 77 still below the minimum standard of 80 with only 38% of students meeting the standard, while the remaining 62% did not. These findings indicate that mathematics learning outcomes at the research school are still relatively low. Learning outcomes in mathematics reflect students' understanding and competence in addressing mathematical problems (Wijayanti & Widodo, 2021). One of the contributing factors to low mathematics achievement is students' perception that mathematics is difficult and stressful, which leads to a lack of interest in learning (Nabillah & Abadi, 2019). Students' interest in learning significantly affects their achievement in mathematics.

The outcome of learning for students can be impacted by intrinsic factors, one of which is learning interest. A study conducted by Atikah & Jumrah (2024) at SMP Negeri 3 Patampanua demonstrated that the mathematics learning outcomes of eighth-grade students were significantly affected by their interest in learning. Students who exhibit a high level of learning interest are generally more motivated and actively involved in the learning process, whereas those with low interest often lack focus and become easily bored. Furthermore, Koleta (2024) emphasized that the higher the students' interest in learning, the better their academic achievement. This indicates that learning interest exerts a positive impact on students' learning outcomes.

In addition to internal factors, ineffective learning models represent external elements that may contribute to poor student learning outcomes. The limited use of learning media and the reliance on traditional methods, where students are treated merely as passive recipients of information, can make the learning process less engaging and participatory (Nabillah & Abadi, 2019; Herlambang et al., 2024). This condition is also evident at SMP Muhammadiyah 5 Surakarta, the site of this study, where mathematics instruction remains dominated by conventional lecture-based methods with minimal integration of technology. As a result, students are often less engaged in the learning process, leading to a limited understanding of the subject matter and learning objectives. Such circumstances highlight a gap between the expected learning approach which should be active, meaningful, and technology-integrated and the reality of classroom instruction. Therefore, it is essential to modernize mathematics education by implementing dynamic and interactive learning strategies supported by appropriate technology. One promising approach is problem-based learning (PBL) integrated with the GeoGebra, which can promote active problem solving and improve conceptual understanding through visual and interactive exploration.

PBL is a learning approach that presents contextual problems to stimulate students' engagement in the learning process (Arruanlebok et al., 2023). According to Musa'ad et al. (2023), PBL model makes learning more engaging and focuses on active student participation by connecting learning to real-world problems. Through PBL, students are presented with contextual challenges that encourage them to

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construct understanding both independently and collaboratively. Group discussions and presentations help students communicate mathematical concepts using appropriate academic language. This process creates a meaningful and interactive learning environment, there by enhancing students' critical thinking skills, conceptual understanding, and learning outcomes (Chanifah et al., 2019). Supporting this, the findings of Maulidiya & Nurlaelah (2019) show that the PBL model greatly enhances students' critical thinking abilities. This means the use of the PBL model has proven effective in improving students' mathematics learning outcomes and the overall learning process (Irawan et al., 2024). To further enhance its effectiveness, PBL can be integrated with technological tools such as GeoGebra.

GeoGebra is an interactive software that helps students visualize mathematical concepts dynamically and engagingly (Nurjamil & Kurniawan, 2017). The integration of this technology in mathematics learning enables students to visualize concepts dynamically, allowing them to understand the relationships between mathematical objects more concretely and intuitively. It also provides opportunities for students to explore, experiment, and discover mathematical ideas independently; facilitates complex mathematical modeling; and enables connections between abstract concepts and real-world contexts (Fatturahmah & Fitrah, 2023). In addition, GeoGebra increases student engagement through interactive simulations, strengthens conceptual understanding, and fosters critical thinking and active problem-solving skills. Research by Suhaifi and Karyono (2021) found that the use of GeoGebra had better outcomes than traditional methods. Similarly, a study by Zulnaidi et al. (2019) showed that the use of GeoGebra improved students' mathematics achievement. These findings suggest a direct correlation between the use of GeoGebra and improved student learning outcomes in mathematics.

The innovative aspect of this research lies in the comparison of the impacts of PBL with and without the integration of GeoGebra on students' mathematics learning outcomes, taking into account students' learning interest as a moderating variable. The GeoGebra integration into PBL model integrates contextual problem-solving with interactive visual exploration, enabling students to construct mathematical concepts independently through dynamic manipulation of mathematical objects. The implementation of this approach encourages meaningful engagement, facilitates deeper comprehension of concepts, and leads to better academic performance.

Most previous studies have focused solely on the effects of PBL and the use of GeoGebra on learning outcomes, without considering students' affective aspects. Thus, this research aims to address this gap in the literature by examining the effects of integrating GeoGebra into PBL on mathematics learning outcomes, while taking into account students' learning interest as an affective factor that has received limited attention in prior research. The objective of this research is to explore whether the integration of GeoGebra into PBL, learning interest, and the interaction between the two influence students' learning outcomes on the topic of similarity. This topic was selected because many students continue to experience conceptual errors when solving problems related to similarity, which are generally caused by limited understanding of its properties, definitions, and terminology (Rahayu, 2016). It is anticipated that the results of this study will support teachers in identifying and implementing more effective, technology-based instructional strategies that align with students' characteristics, there by improving their conceptual understanding of the material being taught.

Based on the aforementioned explanation, this study aims to investigate the effect of the problem-based learning (PBL) approach integrated with GeoGebra on students' mathematics learning outcomes. In addition, it seeks to examine the influence of students' learning interest on their mathematics achievement, as well as to explore the potential interaction between the learning model and learning interest in shaping students' performance in mathematics.

METHODS

This study examined the effects of PBL with GeoGebra integration and PBL without GeoGebra integration on students' mathematics learning outcomes, considering learning interest as a moderating variable. A quantitative method was implemented through a quasi-experimental approach utilizing a post-test-only control group design. Table 1 below presents the design of this study.

Table 1. Research Design

Group	Treatment	Post-test
Experiment	X1	O
Control	X2	O

Description:

X1 = Learning using the PBL model with GeoGebra Integration

X2 = Learning using the PBL model without GeoGebra Integration

O = Learning Outcome Test (Post-test)

This study involved ninth-grade students from Muhammadiyah 5 Surakarta Junior High School. Cluster random sampling was the technique employed for selecting the sample, resulting in two classes with 24 students each. One class was designated as the control group and was taught using the PBL model without GeoGebra, while the other class served as the experimental group and obtained direction using the PBL model integrated with GeoGebra. The study was carried out over three meetings for each class: two meetings were used for treatment implementation, and one meeting was allocated for the administration of the post-test and the distribution of the student learning interest questionnaire. Data for the study were obtained from two instruments: a Learning Interest Questionnaire and a Mathematics Learning

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Outcomes Test, both of which were validated and tested for reliability. The learning interest questionnaire consisted of 16 items using a 4-point Likert scale, while the learning outcomes test comprised 4 essay questions on the topic of Similarity. A two-way ANOVA (2×2 factorial design) was employed to analyze the collected data, focusing on the main effects of learning models and learning interest on mathematics learning outcomes, as well as their potential interaction. Table 2 presents the 2×2 factorial design.

Table 2. 2x2 Factorial Design

Learning Model (A)	Learning Interest (B)	
	High (B1)	Low (B2)
PBL with integration GeoGebra (A1)	A1B1	A1B2
PBL without integration GeoGebra (A2)	A2B1	A2B2

Description:

A1B1 : Mathematics learning outcomes of students with the integration of GeoGebra into PBL model on high learning interest.

A1B2 : Mathematics learning outcomes of students with the integration of GeoGebra into PBL model on law learning interest.

A2B1 : Mathematics learning outcomes of students with the PBL model without integration of GeoGebra on high learning interest.

A2B2 : Mathematics learning outcomes of students with the PBL model without integration of GeoGebra on law learning interest.

The hypotheses examined in this study were as follows: (1) whether the integration of GeoGebra in problem-based learning had a substantial impact on students' mathematics learning outcomes; (2) whether students' learning interest had a substantial impact on mathematics learning outcomes; and (3) whether there was a substantial interaction between the learning model and students' learning interest in influencing mathematics learning outcomes. To evaluate these hypotheses, a two-way ANOVA was employed. The decision criteria were as follows: If the significant value (Sig) was ≤ 0.05, then H_0 was rejected and H_1 was accepted; if the significant value was > 0.05, then H_0 was accepted and H_1 was rejected.

FINDING AND DISCUSSION

Prior to data collection, the two research samples were assessed through baseline equivalence test taken from the midterm exam scores in mathematics, which produced descriptive statistics presented in Table 3 below.

Table 3. Descriptive Statistics of Mathematics Midterm Exam Scores for Baseline Equivalence Test

Class	N	Lowest Value	Highest Value	Average	Standard Deviation
IX-C (Control)	24	70	85	77,71	4,133
IX-D (Experiment)	24	70	89	77,96	4,796

Based on descriptive analysis of mathematics midterm test scores before treatment, the average score for class IX-C was 77.71 and for class IX-D was 77.96, with relatively comparable standard deviations. Thus, the descriptive hypothesis states that there was no significant difference between the preliminary proficiency of the students in the control group and the experimental class before the different learning models were applied.

Furthermore, baseline equivalence test was implemented to ascertain initial math abilities were equivalent between the two groups. The mid-semester mathematics test scores of both classes were analyzed using a t-test, yielding equivalent results. The following table provides a quantitative representation of these findings.

Baseline Equivalence Test

Table 4. Baseline Equivalence Test Results

Test	Class	Sig.	Test Decision	Conclusion
Normality Test	IX-C (Control)	0,463	H0 accepted	Data is normally distributed
	IX-D (Experiment)	0,671	H0 accepted	Data is normally distributed
Homogeneity Test		0,629	H0 accepted	Homogeneous variance data
T-test		0,419	H0 accepted	Equivalent Data

The score data studied must have uniform variation and normal distribution before conducting the equivalence test. As illustrated in Table 4, the data from the Middle Semester Final Assessment for both classes appear to be normally distributed. Specifically, the experimental class shows a Sig. value of 0.671 > 0.05, which supports the null hypothesis (H0). Similarly, the control class demonstrates a Sig. value of 0.463 > 0.05, also supporting the H0. Moreover, the homogeneity test produced a Sig. value of 0.629, which exceeds 0.05. This means that the data's variance is equal, which supports the null hypothesis. Due to the equal variance and normally distributed of the data, the Independent Samples t-test is used to perform the

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baseline equivalence test. This resulted in a Sig value of 0.419 > 0.05, which indicates that H0 is accepted. This finding shows that both the experimental and control classes had comparable pre-treatment math skills. Therefore, both classes can be used as research samples.

The measurement instruments employed in this experiment consist of the questionnaire of learning interest and mathematics learning outcome test questions. The information gathered from the learning outcomes and the mathematics learning interest questionnaire will be tested using the Two-Way ANOVA test. However, normality and homogeneity tests must be conducted as requirements before the test is conducted.

Prerequisite Test

The objective of the normality test is to ascertain whether the sample data aligns with the characteristics of a normally distributed population. In this study, the normality test employs the significance level of 5% of the Shapiro-Wilk method. The data are regarded as normally distributed because they have a value greater than 0.05. Table 5 below presents the analysis results of normality test.

Table 5. Normality Test Results

Data Group	N	Sig.	Decision Test	Summary
A1	24	0,379	H0 accepted	Normally Distributed Data
A2	24	0,564	H0 accepted	Normally Distributed Data
B1	25	0,288	H0 accepted	Normally Distributed Data
B2	23	0,159	H0 accepted	Normally Distributed Data
A1B1	15	0,910	H0 accepted	Normally Distributed Data
A1B2	9	0,941	H0 accepted	Normally Distributed Data
A2B1	10	0,288	H0 accepted	Normally Distributed Data
A2B2	14	0,159	H0 accepted	Normally Distributed Data

As illustrated in Table 5, each group of data demonstrates a Sig value > 0.05. It can be inferred from the results that the data are distributed normally and (H0) is accepted. Consequently, the data can undergo subsequent analysis, specifically the homogeneity test.

If the variances of multiple populations are the same, the purpose of the homogeneity test has been met. When a 5% significance threshold is used in the homogeneity test, a Sig value >0.05 is considered a homogeneous result. Table 6 below will present the homogeneity test.

Table 6. Homogeneity Test Results

Source	Sig.	Test Decision	Summary
Learning Model	0,426	H0 accepted	Homogeneous Variance Data
Learning Interest	0,269	H0 accepted	Homogeneous Variance Data
Levene's Test	0,201	H0 accepted	Homogeneous Variance Data

As demonstrated in Table 6, it is evident that all data groups possess a Sig value > 0.05, which provides support for the null hypothesis and indicates that the variability within the data is consistent across groups. This finding suggests that there is homogeneity in the diversity of data across all groups.

Hypothesis Test

It can be posited that the requirements for hypothesis testing using two-way ANOVA may be met, according to the findings of the normality test of the data distribution and homogeneity of variance of the mathematics learning outcomes test data that have been attached. Table 7 presents the outcomes of the two-way ANOVA test analysis.

Table 7. Two-way ANOVA Test Results

Source	F	Sig.	Test Decision
Learning Model (A)	61.337	.000	H0A is rejected
Learning Interest (B)	99.034	.000	H0B is rejected
Interaction of Learning Model * Learning Interest (AB)	.003	.955	H0AB is accepted

Table 7 shows that the calculated F-value of the learning model obtained Fcount = 61.337 with a Sig value. = 0.000 <0.05, therefore H0A is rejected. This means that there is a substantial comparison of mathematics learning outcomes between the students who participate in the PBL model with GeoGebra integration and the students who participate in the PBL model without GeoGebra integration. The learning interest test result indicates that the value of FcountB = 99.034 and Sig value = 0.000 <0.05, which leads to the rejection of H0B. This finding indicates that the mathematics learning results of students with high interest and students with low interest exhibit substantial differences. In the correlation of learning model and learning interest, the value of FcountAB = 0.003, and the Sig value = 0.955 > 0.05, there by supporting H0AB. This finding revealed that the learning model and learning interest do not have a substantial relationship on the result of mathematics learning.

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Table 8. Summary of Cell Means and Marginal Means

Learning Model	Learning Interest		Marginal Mean
	High	Low	
PBL with GeoGebra	91	73,11	84,29
PBL without GeoGebra	76,90	59,21	66,58
Marginal Mean	85,36	64,65	

Based on the first hypothesis, this finding signifies the rejection of the null hypothesis, thereby indicating a significant impact of the learning method on students' academic performance. Table 8 presents a quantitative overview of this result, showing that the marginal mean of students who learned through the PBL model with GeoGebra was 84.29, while that of students who received PBL without GeoGebra was 66.58. This confirms a substantial disparity in mathematics learning outcomes between students engaged with the PBL–GeoGebra model and those taught through PBL without GeoGebra. Consequently, the integration of GeoGebra into the problem-based learning model has a notable effect on students' mathematics achievement. This is supported by the findings of Utami et al. (2024), who reported that students learning mathematics through a GeoGebra-integrated PBL model demonstrated better outcomes compared to those taught using conventional methods.

However, this study builds on prior research by comparing two active learning approaches—PBL with and without GeoGebra integration—rather than contrasting traditional and modern methods. The improvement in students' learning outcomes is therefore not only attributed to the PBL model itself, but also to the added value of GeoGebra technology in facilitating mathematical understanding. Students using GeoGebra are better able to grasp the relationships between mathematical concepts, as they can observe dynamic changes in graphs, diagrams, or geometric figures in real time. This fosters exploratory learning, enabling students to experiment with multiple solutions through interactive simulations and visualizations. In contrast, students without access to GeoGebra may struggle to interpret abstract concepts, as they rely solely on manual modeling and group discussions. While discussion remains a crucial element of problem-based learning, limited technological tools can hinder optimal conceptual understanding—especially when dealing with more complex or philosophical mathematical ideas.

In the second hypothesis, it shows that H0 is rejected, revealing that students' interest in learning has an impact on their learning outcomes. As illustrated in Table 8, the marginal mean for high level student of learning interest is 85.36, while the marginal mean for low level student learning interest is 64.65. This finding suggests a significant discrepancy in the outcomes of mathematical learning between high and low levels of students' interest in learning. Students who achieve optimal learning outcomes tend to come from students who have high learning interest, in contrast with low interest-of-learning student. The hypothesis is that during the learning process, high interest student tend to show higher levels of enthusiasm, excitement and focus. This, in turn, results in more effective assimilation of the taught lessons, leading to superior learning outcomes. Conversely, students with low interest in learning are often less motivated, easily bored, and make less effort in understanding the material, so their learning outcomes tend to be lower. This result is compatible with the research by Kadarisma et al. (2019), which established a notable correlation between the students' learning interest in mathematics and their mathematical skills. The study found a positive relationship, indicating that students with a strong interest in mathematics tend to perform better on mathematical reasoning tests. Therefore, this study emphasizes that interest in learning acts as an internal motivator that improves students' cognitive abilities in mathematics learning.

The third hypothesis, according to the two-way ANOVA test result, in a Sig value > 0.05. This finding revealed that the interaction of learning models and learning interest are not related to mathematics learning outcomes. Consequently, these two variables work independently in influencing math learning outcomes. The research by Wirdaningsih et al. (2024) indicates similar findings, namely that the learning model of meaningful instructional design and learning interest are not related to students' mathematical reasoning ability. Therefore, although students' learning outcomes may be influenced by learning models and learning interests, these two things do not strengthen or weaken each other in this study.

Thus, this study shows that the PBL model integrated GeoGebra and students' learning interest separately have a positive impact on mathematics learning outcomes, without any interaction between the two. This confirms that the use of interactive technology such as GeoGebra can improve students' understanding, while learning interest remains an important factor in supporting learning success. These findings can serve as a reference for teachers in innovating learning through the integration of learning models with technology, while also considering students' affective aspects to achieve more optimal learning outcomes.

CONCLUSIONS AND RECOMMENDATIONS

In light of the findings, it can be concluded that the integration of GeoGebra into Problem-Based Learning (PBL) is more effective in enhancing students' mathematics learning outcomes compared to the implementation of PBL without GeoGebra. Moreover, students' learning interest emerged as an independent internal factor that significantly contributes to learning achievement, although no interaction effect was observed between the learning model and students' interest.

These results underscore the importance of incorporating technological innovations within active learning frameworks to foster deeper and more meaningful learning experiences. Accordingly, it is recommended that educators integrate tools such as GeoGebra into instructional practices while simultaneously cultivating students' individual learning interest to maximize academic outcomes.

From an academic standpoint, this study enriches the existing body of empirical evidence regarding the impact of educational technology on student performance. Furthermore, it offers a foundation for future research across various educational levels, mathematical domains, and with the inclusion of other cognitive and affective variables, thereby supporting broader generalizability and the development of more holistic instructional models.

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