

## THE EFFECTIVENESS OF PROBLEM-BASED LEARNING ASSISTED BY GEOGEBRA ON JUNIOR HIGH SCHOOL STUDENTS' MATHEMATICS LEARNING OUTCOMES IN SOLID GEOMETRY

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### Abstract

This study aims to examine the differences in the average learning outcomes of students taught using the Problem-Based Learning (PBL) model assisted by GeoGebra and those taught through direct instruction in solid geometry for Grade IX. The research was motivated by the low student achievement, which is largely due to difficulties in understanding the properties of solid figures as well as the limited use of instructional media and inappropriate learning models. This study employed a quantitative approach with a quasi-experimental design of the nonequivalent control group type. The sample consisted of 128 students, divided into two experimental classes and two control classes, selected through random sampling. The research instruments included tests (pretest and posttest), teaching modules, and observation sheets on the implementation of PBL assisted by GeoGebra, all of which were validated by experts. The analysis results revealed that the average posttest scores in the experimental classes (80.69 and 78.63) were higher than those in the control classes (74.38 and 73.28). Hypothesis testing using the independent sample t-test yielded a significance value of  $0.000 < 0.05$ , indicating a significant difference between the two groups. Furthermore, the N-gain analysis showed that the improvement in learning outcomes in the experimental classes (0.47, categorized as moderate) was higher than in the control classes (0.36). Thus, the PBL model assisted by GeoGebra is effective in improving students' mathematics learning outcomes in solid geometry.

**Keywords:** problem-based learning, GeoGebra, learning outcomes, three-dimensional shapes.

### Abstrak

Penelitian ini bertujuan untuk mengetahui perbedaan rata-rata hasil belajar siswa yang diajar dengan model pembelajaran *Problem-Based Learning* (PBL) berbantuan GeoGebra dan siswa yang diajar menggunakan pembelajaran langsung pada materi bangun ruang kelas IX. Penelitian ini dilatarbelakangi oleh rendahnya hasil belajar siswa yang disebabkan karna kesulitan dalam memahami sifat-sifat bangun ruang serta keterbatasan penggunaan media dan penerapan model pembelajaran yang kurang tepat. Penelitian ini merupakan penelitian kuantitatif dengan pendekatan *Quasi-Experiment* tipe *nonequivalent control group design*. Sampel penelitian ini berjumlah 128 siswa yang terdiri dari dua kelas eksperimen dua kelas kontrol yang dipilih melalui teknik *random sampling*. Instrumen penelitian ini berupa tes (*pretest* dan *posttest*), modul ajar dan lembar observasi keterlaksanaan pembelajaran dengan model PBL berbantuan GeoGebra yang telah divalidasi oleh ahli. Hasil analisis menunjukkan bahwa rata-rata nilai *posttest* pada kelas eksperimen (80,69 dan 78,63) lebih tinggi dibandingkan dengan kelas kontrol (74,38 dan 73,28). Uji hipotesis menggunakan *independent sample t-test* menunjukkan nilai signifikansi sebesar  $0,000 < 0,05$ , yang berarti terdapat perbedaan yang signifikan antara kedua kelompok tersebut. Selain itu, hasil analisis N-gain menunjukkan peningkatan hasil belajar pada kelas eksperimen sebesar 0,47 (kategori sedang) lebih tinggi dibandingkan kelas kontrol yakni 0,36. Dengan demikian, model pembelajaran PBL berbantuan GeoGebra baik dalam meningkatkan hasil belajar matematika siswa pada materi bangun ruang.

**Kata kunci:** *problem-based learning*, GeoGebra, hasil belajar, bangun ruang

### INTRODUCTION

Education plays an important role in shaping human resources capable of adapting to the development of science and technology. Education is not only aimed at increasing

knowledge, but also at shaping individuals to have good thinking skills and ethics (Anggreini & Priyojadmiko, 2022). In addition, education also promotes social mobility, thereby minimizing skill gaps within society (Hendrizal et al., 2024). Therefore, improving the quality of education becomes one of the crucial aspects of the education system in order to face the challenges of the times.

Mathematics learning is one of the fundamental aspects that supports this achievement. This is because mathematics learning contributes to the development of logical thinking, critical thinking, and problem-solving skills (Aulia et al., 2023). In line with the objectives of the Merdeka Curriculum, mathematics learning is designed so that students are able to understand and use concepts effectively, logically, and creatively in various contexts (Badan Standar Kurikulum dan Asesmen Pendidikan, 2022). Active and student-centered learning is highly necessary to ensure that learning objectives can be achieved (Ramadhani, 2024).

However, in practice, mathematics learning still faces various challenges, especially in the topic of solid geometry. This is in line with the study conducted by Parindang et al. (2025), which stated that students often experience difficulties in understanding the properties of three-dimensional shapes, calculating surface area and volume, as well as accurately visualizing spatial forms. Such conditions have an impact on the low learning outcomes of students. Learning outcomes themselves refer to the abilities acquired by students after participating in learning and serve as indicators of learning success (Yandi et al., 2023).

The low achievement in mathematics learning can also be caused by a lack of understanding of basic concepts as well as the use of inappropriate learning models and media (Harleni & Mardiana, 2020). This is also supported by the results of interviews with mathematics teachers at SMP Negeri 1 Palu in the 2025/2026 academic year, which revealed that students tend to be passive, lack confidence in answering questions, and that learning is still dominated by direct teaching methods with limited use of media. This condition indicates the need for the implementation of more innovative and interactive learning models.

One of the learning models that can be used is Problem-Based Learning (PBL). Problem-Based Learning (PBL) is a problem-based learning model that places contextual problems as the starting point of learning, thereby encouraging students to analyze, formulate, and solve

problems systematically (Huda et al., 2023). The implementation of PBL is expected to enhance students' activeness and deepen their conceptual understanding.

In addition to learning models, the use of appropriate learning media is also highly needed to increase students' interest and understanding (Laila Raudatul Fauziah, 2020). Attractive learning media can help teachers deliver material more effectively and are expected to improve students' learning outcomes (Wulandari et al., 2023). One of the technology-based learning media that can be used in mathematics learning is GeoGebra. GeoGebra enables dynamic and interactive visualization that can help enhance students' understanding in learning mathematics (Azka, 2024).

Based on the above explanation, it shows the importance of using learning models accompanied by learning media for students to achieve optimal learning outcomes. Although research on the PBL model and the use of GeoGebra has been widely conducted, studies that specifically integrate PBL assisted by GeoGebra in solid geometry material at the junior high school level are still limited. Therefore, this study aims to determine whether there are differences in student learning outcomes between those taught using the Problem-Based Learning (PBL) model assisted by GeoGebra and those taught using direct instruction in solid geometry material for Grade IX students at SMP Negeri 1 Palu.

## **METHOD**

### **Research Design**

This study employed a quantitative approach with a quasi-experimental design using the nonequivalent control group design, which involves experimental and control groups without random assignment of subjects at the individual level (Sugiyono, 2013). In this study, there were two groups: the experimental class and the control class. The experimental class received treatment in the form of instruction using the Problem-Based Learning (PBL) model assisted by GeoGebra, while the control class did not receive such treatment and was taught through direct instruction. Both groups were administered a pretest and posttest to measure students' learning outcomes in solid geometry.

### **Population and Sample**

This study was conducted at SMP Negeri 1 Palu during the second semester of the 2025/2026 academic year. The population of the study consisted of all Grade IX students at SMP Negeri 1 Palu, totaling 352 students. The sample comprised four classes: two

experimental classes, namely IX H and IX K, and two control classes, namely IX C and IX F. The sampling technique employed was random sampling at the class level, with consideration of the equivalence of initial abilities so that each class had an equal opportunity to be selected as the research sample (Sugiyono, 2013).

### **Research Instruments and Learning Procedure**

The research instruments consisted of three main components: a learning achievement test, a teaching module, and an observation sheet for monitoring the implementation of instruction. The learning achievement test comprised essay questions (pretest and posttest) developed based on the alignment of content with learning objectives, readability, and scoring guidelines. The teaching module was designed according to the Problem-Based Learning (PBL) model assisted by GeoGebra, taking into account curriculum alignment, PBL syntax, the use of GeoGebra as a learning medium, as well as linguistic and presentation aspects. The observation sheet was employed to assess the implementation of instruction, covering teacher and student activities, with evaluation criteria including the appropriateness of PBL syntax, clarity of indicators, measurability, utilization of GeoGebra, and consistency of the rating scale. The PBL syntax consisted of five stages: (1) problem orientation, (2) student organization, (3) investigation, (4) development and presentation of results, and (5) evaluation (Farida et al., 2019).

Before the research instruments were employed, a validation test was conducted by experts to ensure their appropriateness in relation to the research objectives. The aspects assessed included content validity and construct validity. Through this process, the instruments used were confirmed to possess an adequate level of reliability in supporting the collection of research data.

### **Analysis Data**

The research data were analyzed using descriptive and inferential statistics. The prerequisite tests included normality and homogeneity tests. Hypothesis testing was conducted using the Independent Samples T-Test at a significance level of 0.05 to determine differences in the average learning outcomes between the experimental and control classes. In addition, N-gain analysis was employed to measure the level of improvement in students' learning outcomes.

## RESULTS AND DISCUSSION

### Descriptive Analysis

The sample consisted of four classes, with two classes serving as the experimental groups (IX H and IX K) and two classes serving as the control groups (IX C and IX F). The sampling technique employed was random sampling at the class level. Descriptive statistics were used to provide an initial overview of students' prior abilities in both the experimental and control groups. The results of the descriptive analysis of the pretest scores are presented in Table 1.

**Table 1. Descriptive Statistics of Pretest Scores**

	Descriptive Statistics					
	N	Range	Minimum	Maximum	Mean	Std. Deviation
Pre-Test Eksperimen H	32	27	48	75	60,25	6,984
Pre-Test Eksperimen K	32	25	50	75	60,81	6,784
Pre-Test Kontrol C	32	33	40	73	59,19	7,385
Pre-Test Kontrol F	32	30	45	75	58,25	8,915
Valid N (listwise)	32					

Based on Table 1, it can be concluded that the initial abilities of students in the experimental and control classes were relatively similar. This indicates that the average scores of both groups did not differ significantly prior to the implementation of the instructional treatment.

After the treatment was administered to the experimental classes, the average posttest scores of students in the experimental groups showed a greater increase compared to those in the control groups, as presented in Table 2.

**Table 2. Descriptive Statistics of Posttest Scores**

	Descriptive Statistics					
	N	Range	Minimum	Maximum	Mean	Std. Deviation
Post-Test Eksperimen H	32	30	65	95	80,69	6,528
Post-Test Eksperimen K	32	23	70	93	78,63	5,615
Post-Test Kontrol C	32	27	58	85	74,38	7,223
Post-Test Kontrol F	32	28	60	88	73,28	6,171
Valid N (listwise)	32					

Based on Table 2, the average posttest scores indicate that the learning outcomes of the experimental classes were higher than those of the control classes after the implementation of the instructional treatment, namely the Problem-Based Learning (PBL) model assisted by GeoGebra.

### Normality and Homogeneity Tests

The normality test was conducted to determine whether the pretest and posttest data were normally distributed or not. The testing was carried out using SPSS 21 with the One-Sample Kolmogorov test, since the sample size was greater than 50. The results of the normality test are presented in Table 3.

**Table 3. Normality Test Results of Pretest and Posttest Scores**

		Tests of Normality		
Class		Kolmogorov-Smirnov <sup>a</sup>		
		Statistic	df	Sig.
Hasil	Pretest Kelas Eks H	,108	32	,200*
	Posttest Kelas Eks H	,128	32	,195
	Pretest Kelas Eks K	,110	32	,200*
	Posttest Kelas Eks K	,126	32	,200*
	Pretest Kelas Kont C	,144	32	,091
	Posttest Kelas Kont C	,130	32	,186
	Pretest Kelas Kont F	,113	32	,200*
	Posttest Kelas Kont F	,140	32	,111

Based on the results of the normality test for the pretest and posttest in Table 3, the significance (sig.) values for all pretest and posttest data in both the experimental and control classes were greater than 0.05. The criterion for data to be normally distributed is a significance value greater than 0.05; therefore, it can be concluded that all pretest and posttest data were normally distributed. Thus, the research data met the assumption of normality.

The homogeneity test was conducted to examine whether the variance of the data from the analyzed samples was homogeneous or not. The results of the homogeneity test for the pretest data are presented in Table 4, and the results of the homogeneity test for the posttest data are presented in Table 5.

**Table 4. Homogeneity Test Results of Pretest Data**

		Test of Homogeneity of Variance			
		Levene			
		Statistic	df1	df2	Sig.
Pre	Based on Mean	2,338	1	126	,129
	Based on Median	2,593	1	126	,110
	Based on Median and with adjusted df	2,593	1	124,711	,110
	Based on trimmed mean	2,428	1	126	,122

Based on the results of the homogeneity test of variance using Levene's test, the obtained P-value was 0.129. This value is greater than the chosen significance level of 0.05. Since the P-value > 0.05, the null hypothesis ( $H_0$ ) is accepted (there is not enough evidence to

reject  $H_0$ ). Therefore, it can be concluded that the variance of the pretest data between the experimental and control classes is homogeneous.

**Table 5. Homogeneity Test Results of Posttest Data**

Test of Homogeneity of Variance					
		Levene Statistic	df1	df2	Sig.
Post	Based on Mean	,443	1	126	,507
	Based on Median	,400	1	126	,528
	Based on Median and with adjusted df	,400	1	125,875	,528
	Based on trimmed mean	,440	1	126	,508

Based on the results of the homogeneity test of variance using Levene's test, the obtained P-value was 0.507. This value is greater than the chosen significance level of 0.05. Since the P-value  $> 0.05$ , the null hypothesis ( $H_0$ ) is accepted (there is not enough evidence to reject  $H_0$ ). Therefore, it can be concluded that the variance of the posttest data between the experimental and control classes is homogeneous.

### Hypothesis Testing

Hypothesis testing in this study was conducted using the t-test. This test was employed to determine whether there was a significant difference between the average learning outcomes of students in the experimental class, which was taught using the PBL learning model assisted by GeoGebra, and the control class, which was taught through direct instruction. The results of the t-test are presented in Table 6.

**Table 6. t-test Results**

Independent Samples Test				
t-test for Equality of Means				
		df	Sig. (2-tailed)	Mean Difference
Learning Model	Equal variances assumed	126	,000	5,828
	Equal variances not assumed	125,055	,000	5,825

Based on the results of the independent samples t-test, the obtained significance value was  $0.000 < 0.05$ . This indicates that there is a significant difference between the average learning outcomes of students in the experimental class and those in the control class. In addition, the mean difference was 5.828, which means that the average learning outcomes of students in the experimental class were higher than those of students in the control class.

### N-gain Test

The N-gain test was employed to determine the extent of improvement in students' average learning outcomes before and after the treatment, namely instruction using the Problem-Based Learning (PBL) model assisted by GeoGebra in solid geometry. In addition, the N-gain test provided information regarding the achievement level of students' learning outcomes. The results of the data analysis are presented in Table 7.

**Table 7. Results of the N-gain Test**

Group	Normalized N-gain Value	Category
Experimental Class	0,47	Medium
Control Class	0,36	Medium

Based on the results of the N-gain test presented in Table 7, the normalized N-gain value for the experimental classes was 0.47, while that of the control classes was 0.36. Both values fall within the moderate category; however, the N-gain of the experimental classes was higher than that of the control classes. Although the improvement did not reach the high category, these findings demonstrate that problem-based learning supported by interactive visual media such as GeoGebra is more effective than direct instruction in enhancing students' learning outcomes.

## Discussion

The results of the study indicate a significant difference between the average learning outcomes of students taught using the PBL model assisted by GeoGebra and those taught through direct instruction. This difference demonstrates that the use of the PBL model assisted by GeoGebra has a more positive impact on students' mathematics learning outcomes. Theoretically, these findings can be explained through the perspective of constructivist learning theory, which emphasizes knowledge as a human construction developed through interactions with objects, phenomena, experiences, and the environment. This means that students build their own knowledge and skills and actively seek understanding from what they learn (Nerita et al., 2023).

The PBL model provides students with opportunities to engage in solving contextual problems, thereby fostering deeper understanding. Within this model, students actively participate in investigative activities, group discussions, and problem-solving processes (Aprina et al., 2024). Through these stages, students are trained to develop critical thinking skills, collaborate effectively, and communicate the outcomes of their discussions during the learning process.

"In addition, the use of GeoGebra as a learning medium helps students directly understand mathematical concepts, particularly in solid geometry. The dynamic visualizations provided by GeoGebra enable students to observe, manipulate, and comprehend three-dimensional shapes more concretely. Thus, the combination of problem-based learning and interactive media makes the learning process more student-centered.

The implementation of instruction was also observed through observation sheets covering both teacher and student activities. The results showed that the teacher's activities in applying the steps of the PBL model assisted by GeoGebra were carried out effectively, while the students' activities reflected active engagement in understanding problems, participating in group discussions, and utilizing GeoGebra to comprehend solid geometry concepts. These findings indicate that the application of PBL assisted by GeoGebra was not only well-executed from the teacher's role as facilitator but also effective in encouraging student participation, enhancing interaction, and strengthening the understanding of solid geometry through more concrete visual representations.

The findings of this study are further supported by the results of the N-gain test for the experimental and control classes, which showed that the average normalized N-gain value for the experimental classes was 0.47, while that of the control classes was 0.36. This indicates that the improvement in students' learning outcomes in the experimental classes was higher than in the control classes, as reflected by the values  $0.47 > 0.36$ . These results suggest that a learning model involving problem-solving supported by technology can better assist students in understanding the material compared to direct instruction. Nevertheless, the improvement in learning outcomes was still influenced by the limited time available for implementing the model, meaning that students had not yet fully adapted to problem-based learning.

The findings of this study are consistent with those of Rohmana et al. (2025), who reported that the problem-based learning model assisted by GeoGebra can enhance students' mathematical problem-solving skills. Furthermore, Khurniati et al. (2023) also demonstrated that the implementation of problem-based learning assisted by GeoGebra yields better results in students' conceptual understanding of mathematics compared to instruction without GeoGebra or direct teaching. Thus, the results of this study reinforce previous

findings that the use of innovative learning models supported by technology can improve the quality of mathematics education.

Based on the results of this study, it can be concluded that the implementation of the problem-based learning model assisted by GeoGebra has a positive effect on students' mathematics learning outcomes in solid geometry.

## CONCLUSION

Based on the results of the study and data analysis, it can be concluded that there is a significant difference between the average learning outcomes of the experimental classes taught using the PBL model assisted by GeoGebra and the control classes taught using direct instruction in solid geometry at SMP Negeri 1 Palu. This conclusion is supported by the results of the independent sample t-test, which showed a significance value of  $0.000 < 0.05$ . In addition, the mean difference was 5.828, indicating that the average learning outcomes of the experimental classes were higher than those of the control classes. The N-gain test results also showed a value of 0.46, which falls within the moderate category, suggesting that the implementation of the PBL model assisted by GeoGebra had a positive impact and was able to improve students' learning outcomes. The combination of problem-based learning and interactive media encouraged active student engagement and facilitated more meaningful conceptual understanding. Therefore, the PBL model assisted by GeoGebra can be considered an effective and interactive alternative for improving students' mathematics learning outcomes in solid geometry.

These findings imply that the implementation of problem-based learning accompanied by interactive technological media is capable of creating meaningful learning, increasing student engagement, and supporting conceptual understanding. This demonstrates that the results of this study align with student-centered learning supported by interactive media, as emphasized in the Merdeka Curriculum.

Based on the results of this study, it is recommended that mathematics teachers consider implementing the PBL model assisted by GeoGebra as an alternative instructional strategy to improve students' learning outcomes. The use of technology such as GeoGebra in mathematics instruction is expected to foster greater student independence and enable them

to keep pace with the demands of the digital era. Future research may expand the scope to different topics, educational levels, and examine additional variables.

## ACKNOWLEDGEMENT

The author would like to express the deepest gratitude and sincere appreciation to the supervising lecturer for the guidance and valuable input provided during the preparation of this research. Special thanks are also extended to the expert validator lecturer for the constructive feedback, support, and valuable validation. The author would also like to thank the Principal of SMP Negeri 1 Palu, the mathematics teacher, and the students for their support and willingness to participate in this study. Finally, the author expresses heartfelt gratitude to all parties who have contributed to the smooth process of this research, enabling it to be successfully completed.

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