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THE EFFECTIVENESS OF *GEOGEBRA*-ASSISTED *PROBLEM BASED LEARNING* ON STUDENTS' MATHEMATICAL LITERACY IN SOLID GEOMETRY

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ABSTRACT

This study aims to examine the effectiveness of the *Problem-Based Learning* (PBL) learning model assisted by *GeoGebra* on the mathematical literacy skills of ninth-grade students on the material of spatial figures. This study uses a quantitative approach with a *quasi-experimental* research type with a *pretest-posttest control group design*. The population in this study involved all ninth-grade students in one of the junior high schools in Palu City, with samples selected using *cluster random sampling* techniques, namely class IX F as the experimental class and class IX I as the control class. Data collection was carried out through a descriptive test to measure students' mathematical literacy skills. Data analysis was carried out using an *independent sample t-test* and an *N-gain* test with a significance level of 0.05. The results showed that the *Sig. (2-tailed)* value was 0.001, which means there was a significant difference between the experimental class and the control class. The average N-gain in the experimental class was 0.48 which was included in the medium category, higher than the control class of 0.23 which was included in the low category. Thus, it can be concluded that the *Problem-Based Learning* (PBL) learning model assisted by *GeoGebra* is effective in improving students' mathematical literacy skills in spatial geometry material and can be an alternative in mathematics learning.

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1. INTRODUCTION

Education is a fundamental aspect of human life, playing a role in developing individual potential and shaping quality character. Through education, people are expected to become knowledgeable, skilled, and contribute to society (Yayan Alpian, et al., 2019; Yusida 2020). In the context of formal education, mathematics is one of the important subjects taught at every level of education because it has a strategic role in supporting the development of knowledge and logical thinking skills of students (Suprayo et al., 2023; Halard, et al., 2020).

One of the most difficult topics in mathematics is spatial geometry. This material requires strong visualization and analytical skills because it involves three-dimensional objects that cannot always be observed directly (Indah Purnama Sari, et al., 2022; Fajari 2020). This condition causes some students to experience difficulties in understanding the concept of spatial shapes, which ultimately has an impact on low mathematical literacy skills.

In general, literacy is defined as the ability to read and write, but as time goes by, its meaning has expanded to include the ability to understand and use information in various contexts (Amri & Rochmah, 2021). In the context of mathematics, mathematical literacy is an individual's ability to formulate, use, and interpret mathematics to solve problems in everyday life (Suharyono & Rosnawati, 2020). This is in line with the definition put forward by the OECD through the *Programme for International Student Assessment* (PISA) in 2022, which states that mathematical literacy is an individual's ability to formulate, use, and interpret mathematics in various life contexts, which involves mathematical reasoning and the appropriate use of mathematical concepts, procedures, facts, and tools.

Mathematical literacy skills are very important for students to have because they can help them think systematically, understand problems, and make logical decisions in everyday life (Wiji Surtika, 2024). However, various studies show that students' mathematical literacy skills are still relatively low (Sarah Nur Hanifah, 2023). The difficulties students experience include understanding problem information, developing problem-solving strategies, and drawing appropriate conclusions. These difficulties are influenced by various factors, such as a lack of conceptual understanding, inaccuracy, and low self-confidence (Nuraida 2023).

Furthermore, interviews with math teachers at a junior high school in Palu City revealed that students tend to be less active in learning. This is due to a limited understanding of basic mathematics and a lack of courage in expressing opinions. One factor suspected to be contributing to this situation is the inappropriate use of learning models and media (Harleni & Mardiana 2020). Therefore, innovation in learning is needed that can optimally increase student activity and understanding.

One of several learning models that can be used is *Problem-Based Learning* (PBL), which emphasizes solving contextual problems to develop students' critical thinking and *problem-solving* skills. (Marta Towe, 2021; Anisah, et al., 2024). This model can be combined with the use of technology-based learning media, such as *GeoGebra*, which is able to visualize mathematical concepts in a more concrete and interactive way (Indayanti, 2023; Pohan & Siregar, 2021). The use of *GeoGebra* in *problem-based learning* can increase student engagement, help visual understanding of concepts, and increase student interest in learning (Puspasari, 2022).

Several previous studies have shown that the use of innovative learning models, such as *Problem-Based Learning* (PBL), can improve students' critical thinking and problem-solving skills. Furthermore, the use of technology-based learning media such as *GeoGebra* has also been shown to facilitate more concrete and interactive visualization of mathematical concepts.

However, most of this research focuses on improving learning outcomes or problem-solving skills and has not specifically examined students' mathematical literacy, particularly in the area of spatial geometry. Furthermore, studies integrating PBL models with *GeoGebra* to improve students' mathematical literacy are still limited.

Therefore, this research is novel in combining the PBL model with *GeoGebra* media, focusing on improving students' mathematical literacy skills in spatial geometry.

This research is expected to contribute empirical evidence regarding the effectiveness of the *GeoGebra*-assisted PBL learning model in improving students' mathematical literacy skills, as well as serve as a reference for teachers in developing more innovative and interactive learning.

Based on the description, this study aims to determine the effectiveness of the *Problem-Based Learning* (PBL) learning model assisted by *GeoGebra* in improving the mathematical literacy skills of grade IX students of SMP Negeri 2 Palu on the material of spatial figures.

2. METHOD

This research used a quantitative approach with a (*quasi-experimental*) method. This design involved two groups: an experimental group and a control group. Both groups were given a *pretest*, then given different treatments, and concluded with a *posttest* to measure students' mathematical literacy skills.

The experimental group was taught using the *Problem-Based Learning* (PBL) model with the assistance of *GeoGebra,* while the control group used the direct learning model. The research design is presented in Table 1.

Tabel 1. Research Design

Class	*Pretest*	Treatment	*Posttest*
Experiment	O_1	X	O_2
Control	O_3		O_4

Note: In this study, X is the application of the *Problem-Based Learning* (PBL) learning model assisted by *GeoGebra.*

This research was conducted at a junior high school in Palu City during the odd semester of the 2025/2026 academic year. The study population consisted of all 358 ninth-grade students spread across 11 classes. *Random sampling* was used to select two classes: the experimental class and the control class.

Quantitative data was collected in the form of students' mathematical literacy scores. The primary data source was the *pretest* and *posttest* results given to both groups. In addition, observational data was collected to assess the effectiveness of learning using the *GeoGebra*-assisted PBL model.

The research instruments used included: (1) teaching modules and Student Worksheets (LKPD), (2) essay-based tests as *pretests* and *posttests* to measure students' mathematical literacy, and (3) observation sheets to assess the effectiveness of the learning model. All instruments were validated by experts to ensure content and construct validity before being used in the study.

Data analysis techniques were conducted using descriptive and inferential statistics. To determine the effectiveness of the learning model, an *N-gain* analysis was conducted to observe the increase in student scores from *pretest* to *posttest*. This increase can be measured using *pretest* and *posttest* score data (Lestari and Yudhanegara, 2018). The calculation of the *N-gain* formula can be seen in the following equation.

$$N\text{-}gain = \frac{Posttest - Pretest}{\text{maximum score} - Pretest}$$

Based on the *N-Gain* value, the increase in students' mathematical literacy is categorized as presented in Table 2.

Table 2. Level Criteria *N-Gain*

N-Gain Value	Category
N-Gain > 0.70	High
0.30 ≤ *N-Gain* ≤ 0.70	Medium
N-Gain < 0.30	Low

Lestari & Yudhanegara (2018)

A learning model is considered effective if the *N-gain* value is in the moderate or high category.

Before hypothesis testing, prerequisite tests were conducted, including normality and homogeneity tests using SPSS *software*. The *Kolmogorov-Smirnov* test was used for normality, while the Levene test for homogeneity was used for homogeneity. Data were considered normal and homogeneous if the significance value was greater than 0.05.

Hypothesis testing was conducted using an independent two-sample t-test with a significance level of 0.05 to determine whether there were differences between the two groups. The research hypothesis was formulated as follows:

H_0: The *Problem-Based Learning* model assisted by *GeoGebra* media is not effective in improving students' mathematical literacy skills compared to students who participate in direct learning.

H_1: The *Problem-Based Learning* model assisted by *GeoGebra* media is effective in improving students' mathematical literacy skills compared to students who participate in direct learning.

3. RESULTS AND DISCUSSION

3.1. Results

This section presents research findings based on descriptive statistics, *N-gain* analysis, prerequisite tests, hypothesis testing, and observation results of the implementation of the *GeoGebra*-assisted *Problem-Based Learning* (PBL) learning model.

A. Descriptive Statistics

Descriptive analysis was conducted to describe the initial and final abilities of students in the experimental and control classes. The results showed that the average *pretest* scores in the experimental class were relatively equivalent to those in the control class and still below the Minimum Completion Criteria (KKM), indicating that students' initial abilities were still low. The *pretest* results for students in the experimental and control groups are presented in Table 3 below.

Table 3. *Pretest* Data of the Control and Experimental Classes

Class	N	Lowest	Highest	Range	Mean	Standard Deviation
Control	28	38.33	76.67	38.33	46.37	7.55
Experiment	28	38.33	65.00	26.67	52.08	6.71

The following Table 4 contains data on the *posttest* results of students in the experimental group and the control group.

Table 4. *Posttest* Data of the Control and Experimental Classes

Class	N	Lowest	Highest	Range	Mean	Standard Deviation
Control	28	45.00	68.33	23.33	60.24	6.03
Experiment	28	61.67	95.00	33.33	76.01	10.55

After receiving the treatment, the average *posttest* score in the experimental class increased significantly. The experimental class achieved an average of 76, while the control class only achieved an average of 60.

These results indicate that students' mathematical literacy skills in the experimental class were higher than those in the control class. Furthermore, to determine the extent of the increase in students' mathematical literacy skills, an *N-gain* analysis was conducted on each student in both classes.

N-Gain Analysis

An *N-gain* calculation was performed to determine the extent of improvement in students' mathematical literacy skills. The results of the *N-gain* calculation for the experimental and control classes are presented in Table 5 below.

Table 5. *N-Gain* Test Results

Group	*Pretest* Mean	*Posttest* Mean	*N-Gain*	Category
Control	46.37	60.24	0.23	Low
Experiment	52.08	76.01	0.48	Medium

Note: The average *N-gain* is calculated based on the score obtained by each student in each group.

The results of the *N-gain* analysis showed that the average *N-gain* in the experimental class was 0.48, which is considered moderate, while in the control class it was 0.23, which is considered low.

Improvement in students' mathematical literacy was analyzed using each student's normalized *N-gain* score. Prior to hypothesis testing, the *N-gain* scores were subjected to prerequisite tests of normality and homogeneity.

B. Prerequisite Test

Normality Test

A normality test was conducted to ensure that the data on students' mathematical literacy skills in spatial geometry across all sample groups were normally distributed. The following analysis uses the *Kolmogorov-Smirnov* test via SPSS on the results of the *N-gain* test on the *pretest* and *posttest* of students in the experimental and control groups, which are presented in Table 6.

Table 6. Normality Test Results Data on Values from the *N-gain* Test

Group	*Statistic*	df	Sig.
Control	0.159	28	0.067
Experiment	0.143	28	0.152

The results of the normality test using the *Kolmogorov-Smirnov* test showed that all *N-gain* test values for the *pretest* and *posttest* data for the experimental and control classes had a significance value of more than 0.05. Thus, it can be concluded that the data are normally distributed.

Homogeneity Test

A homogeneity test was conducted to ensure that the variance of the *pretest* and *posttest* data on students' mathematical literacy in the experimental and control groups was homogeneous, as a requirement for hypothesis testing. A summary of the homogeneity test results is presented in Table 7 below.

Table 7. Homogeneity Test Result Data on the Value of the *N-gain* Test

	Levene Statistic	Sig.
Based on Mean	2.029	0.160

Based on the results of the homogeneity test using the *Levene's Test* technique, a significance value for the *N-gain* data of 0.160 was obtained. Considering the Sig. value of 0.160 > 0.05, the homogeneity prerequisite is met, which means that the increase data (*N-gain*) in both research groups have the same variance or are homogeneous.

Hypothesis Testing

Because the students' mathematical literacy data were normally distributed and had homogeneous variance, analysis was performed using *an independent sample t-test* in SPSS. This test was used to determine whether the *GeoGebra*-assisted *Problem-Based Learning* Model was effective in improving students' mathematical literacy skills compared to students who participated in direct learning. The results of the hypothesis test are presented in Table 8 below.

Tabel 8. Independent Samples t-Test Results

Group	*Sig.(2-tailed)*	*Mean Difference*
Equal variances assumed	0.001	25.02448
Equal variances not assumed	0.001	25.02448

Hypothesis testing was conducted using an *independent sample t-test*. The test results showed that the significance value *(Sig. 2-tailed)* of 0.001 was smaller than 0.05. Therefore, H_0 was rejected and H_1 was accepted. This indicates that the *Problem-Based Learning* Model assisted by *GeoGebra* media is effective in improving students' mathematical literacy skills compared to students who participated in direct learning.

Observations on the Implementation of the *Problem-Based Learning* Model

Observation data was collected to assess the implementation of the *Problem-Based Learning* (PBL) model during learning activities in the experimental class. Based on the observations, each stage of the PBL model problem orientation, student organization, investigation guidance, development and presentation of results, and analysis and evaluation of the problem-solving process was implemented in accordance with the learning plan.

Throughout the learning process, students actively participated. In the problem orientation stage, students considered the contextual problem presented through *GeoGebra*

to understand the given situation. In the organization stage, students began working collaboratively in groups to design steps to solve the problem. Next, in the investigation stage, students explored using *GeoGebra*, such as manipulating objects or observing changes to discover related concepts. In the development and presentation stage, students presented their discussion results and solutions to the class. In the final stage, analysis and evaluation, students and the teacher reflected on the process and concluded the concepts of prisms and cylinders they had learned.

In general, the observation results show that the implementation of *the Problem Based Learning* (PBL) model is running well and is able to encourage student activity during learning.

3.2. Discussion

This study involved two classes at a junior high school in Palu City, consisting of an experimental class and a control class, with 28 students each. The study focused on the application of the *Problem-Based Learning* (PBL) model with the help of *GeoGebra* to measure its effectiveness on students' mathematical literacy skills in spatial geometry.

Based on descriptive analysis, the initial ability of students as indicated by the average *pretest* score in the experimental group is in a relatively low category, namely 52, while in the control group it is 46. All of these scores have not reached the Minimum Completion Criteria (KKM), thus indicating that the initial ability of students in the material of spatial figures is still relatively low and relatively equal. The equality of initial abilities between the two groups is an important basis in experimental research so that differences in learning outcomes after treatment can be compared objectively. This finding is in line with research by Suroso dan Kuncahyono, (2021) which states that pretests are used to determine students' initial abilities before being given learning treatment so that the equality of initial abilities between groups can be known.

After being given treatment, the posttest results showed a significant increase in the experimental group compared to the control group. The average score in the experimental class reached 76, while in the control class it only reached 60. These results indicate that the *Problem-Based Learning* model assisted by *GeoGebra* media is effective in improving students' mathematical literacy skills compared to students who participated in direct learning. Descriptively, this finding is in line with the research of Widya Kusumawati, dkk., (2024) which stated that the *GeoGebra*-assisted *Problem-Based Learning* model is effective in improving students' mathematical literacy skills.

The improvement of students' mathematical literacy skills was also strengthened through the results of the *N-gain* test. The average *N-gain* in the experimental group was 0.48, which is in the medium category, while in the control group it was 0.23, which is in the low category. This indicates that the improvement in students' mathematical literacy skills in the experimental group was higher than in the control group. The improvement in students' mathematical literacy skills was analyzed using a normalized *N-gain* score. The use of *N-gain* aims to determine the level of improvement in students' abilities before and after being given a learning treatment. This finding is in line with the research of Nida Amelya Al Fitriani, etc., (2023) which stated that the *N-gain* value can be used to see the effectiveness of learning through improving student learning outcomes. Before the hypothesis test was conducted, the *N-gain* score was tested for prerequisites through normality and homogeneity tests. Then, the results of the prerequisite test showed that the research data met the statistical assumptions. The normality test using the *Kolmogorov-Smirnov* test at a significance level of 0.05 indicated that the *N-gain* scores were normally distributed. Furthermore, the homogeneity test showed that the *N-gain* data in the

experimental and control groups were homogeneous with a significance value of 0.160 ($p > 0.05$).

Based on the fulfillment of the prerequisite tests, a hypothesis test was conducted using an independent sample t-test. The test results showed a significance value of 0.001, which is less than 0.05. Thus, it can be concluded that the *GeoGebra*-assisted *Problem-Based Learning* model is effective in improving students' mathematical literacy skills compared to students who participated in direct learning. The results of this study are also in line with previous research which stated that the application of the *GeoGebra*-assisted *Problem-Based Learning* model is effective in improving students' mathematical literacy skills compared to conventional learning (Widya Kusumawati, dkk., 2024). Thus, the *GeoGebra*-assisted *Problem-Based Learning* learning model is declared effective for students' mathematical literacy skills.

This improvement occurred because the *Problem-Based Learning* (PBL) model emphasizes student-centered learning through the presentation of contextual problems. Students not only receive information but also actively explore and solve the problems presented. This aligns with suswati (2021) opinion, which states that *Problem-Based Learning* helps create a learning environment that begins with relevant problems, thus providing a more meaningful learning experience.

In its implementation, during the problem orientation stage, the teacher presents contextual information related to geometric shapes using *GeoGebra*. *GeoGebra* allows students to visualize geometric shapes interactively, thus facilitating conceptual understanding. During the organization stage, students work in groups to discuss the problem, which encourages interaction and collaboration. This finding aligns with research that states that *GeoGebra* can help visualize geometric shapes, thereby enhancing students' understanding of the concept of spatial geometry (Meganingtyas, 2021). Furthermore, the implementation of the *Problem-Based Learning* model encourages students to actively think and collaborate in solving learning problems.

Next, in the investigation stage, students explore using *GeoGebra* to understand concepts such as surface area and volume. This activity helps students discover concepts independently and trains mathematical literacy skills, such as translating problems into mathematical forms and using logical reasoning. These findings align with research that states that using *GeoGebra* in mathematics learning can help students explore concepts independently and improve mathematical understanding through interactive visualization (Meganingtyas, 2021). In the presentation stage, students present the results of their discussions, which trains mathematical communication skills. The final stage, reflection, helps students evaluate the learning process and outcomes. Furthermore, the *Problem-Based Learning* model can improve students' mathematical communication skills through discussions, presentations, and group *problem-solving* activities (Luthfia Laili Ayu Novitasari, et al., 2024).

The results of this study are also supported by previous research, namely Nurul Hidayati, et al., (2025) which shows that the application of the *Problem-Based Learning* model can significantly increase student activity and learning outcomes. Furthermore, research by Elnita Nababan dan Yanty Maria Marbun (2024) also demonstrated that the *Problem-Based Learning* model is effective in improving students' understanding of mathematics concepts and learning outcomes.

Thus, based on the results of data analysis and support from previous research, it can be concluded that the application of the *Problem-Based Learning* (PBL) model assisted by *GeoGebra* is effective in improving students' mathematical literacy skills in spatial geometry material.

4. CONCLUSION

Based on the research results and discussion, it can be concluded that the application of the *GeoGebra*-assisted *Problem-Based Learning* (PBL) model is effective in improving students' mathematical literacy skills in the material of spatial figures. This is proven by the results of the *N-gain* test which shows that the average increase in students' mathematical literacy skills in the experimental class is 0.48 with a medium category, while in the control class it is 0.23 with a low category. In addition, the results of the hypothesis test using the *independent sample t-test* show a significance value of 0.001, which is smaller than 0.05. These results indicate that there is a significant difference in the increase in mathematical literacy skills between the experimental class and the control class. Thus, the *GeoGebra*-assisted *Problem-Based Learning* (PBL) model is proven to be able to provide a more optimal contribution to the development of students' mathematical literacy compared to direct learning.

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