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The Effectiveness of GeoGebra-Assisted Problem-Based Learning with a Deep Learning Approach on Critical Thinking Skills

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Abstract
Critical thinking is a higher-order thinking skill that needs to be developed in mathematics education. However, students' proficiency in this area remains relatively low. This study aims to analyze the effectiveness of Problem-Based Learning (PBL) integrated with a GeoGebra-assisted deep learning approach on students' critical thinking skills. This research employed a quantitative method with a pretest-posttest control group design. The sample comprised two eighth-grade classes at SMP Negeri 41 Semarang, selected through a cluster random sampling technique, consisting of an experimental group of 32 students and a control group of 32 students. The experimental group was subjected to PBL with a GeoGebra-assisted deep learning approach, whereas the control group received standard PBL instruction. Data were collected using a critical thinking skills test that had met the validity and reliability criteria. The data were subsequently analyzed using a classical mastery test, an independent sample t-test (test of two means), and a test of two proportions. The results indicated that the experimental class achieved classical learning mastery, demonstrated a higher average in critical thinking skills, and showed a greater proportion of mastery compared to the control class. Consequently, the application of PBL combined with a GeoGebra-assisted deep learning approach is effective in enhancing students' critical thinking skills and can serve as an innovative alternative strategy in mathematics instruction.

Keywords: critical thinking skills; deep learning; GeoGebra; problem-based learning

INTRODUCTION

Education in the modern era faces the challenge of developing the higher-order thinking skills necessary to navigate real-world complexities. One crucial higher-order thinking skill to cultivate in the learning process, particularly at the junior high school level, is critical thinking. This skill is essential to equip students to think critically when confronting various problems, especially in mathematics. Interviews conducted with an eighth-grade mathematics teacher at SMP Negeri 41 Semarang revealed several issues within the instructional process, one of which is the students' low critical thinking skills. Preliminary test results indicated that only 27% of students achieved mastery, while the remaining 73% failed to reach the mastery level when solving non-routine mathematical problems. This condition suggests that the applied instructional process has not fully facilitated students in developing their critical thinking skills.

Critical thinking is a process of analysis, evaluation, solution-seeking, and conclusion-drawing (Cynthia & Sihotang, 2023). It is a vital proficiency that must be developed by students as it plays a significant role in helping them solve mathematical problems appropriately when faced with challenges (Anita & Firmansyah, 2022). Students with low critical thinking skills exhibit deficiencies in planning and executing problem-solving strategies (Rizqiani et al., 2023). Therefore, an

instructional model capable of actively engaging students in the problem-solving process is required. Problem-Based Learning (PBL) is an instructional model recognized for its effectiveness in increasing student engagement, fostering in-depth material comprehension, and enhancing critical thinking skills (Rosadah et al., 2024). PBL can be integrated with a deep learning approach to strengthen the educational process, focusing not only on problem-solving but also on profound conceptual understanding and the development of students' critical reasoning skills.

The deep learning approach is enriched by mindful, meaningful, and joyful principles, which render the learning process more holistic. This approach facilitates students in connecting educational material to real-world situations, thereby increasing their interest and motivation to actively participate in learning (Sari et al., 2025). In the current digital era, educational technologies such as GeoGebra assist in improving the effectiveness of mathematics instruction. GeoGebra helps students explore mathematical concepts more deeply and enhances their conceptual understanding in an interactive and intuitive manner (Awaji et al., 2025). This study is expected to contribute to improving the effectiveness of instructional model implementation in enhancing students' critical thinking skills.

METHOD

This study employed a quantitative approach with a pretest-posttest control group design. The research was conducted at SMP Negeri 41 Semarang during the 2025/2026 academic year. The research population comprised all eighth-grade students. The sample was selected using a cluster random sampling technique, resulting in two classes: class VIII-B as the experimental group with 32 students, and class VIII-A as the control group with 32 students.

The experimental group received Problem-Based Learning (PBL) with a GeoGebra-assisted deep learning approach, while the control group received standard PBL instruction. The independent variable in this study was the PBL integrated with a GeoGebra-assisted deep learning approach, whereas the dependent variable was the students' critical thinking skills. The research instrument was a critical thinking skills test that had met the validity and reliability criteria.

Data analysis was conducted quantitatively using a classical learning mastery test, an independent sample t-test, and a test of two proportions. The instructional approach was considered effective if the students achieved classical mastery, demonstrated a higher average in critical thinking skills, and showed a greater proportion of learning mastery in the experimental group compared to the control group. The hypothesis testing was performed using IBM SPSS 32 software at a 5% significance level.

RESULTS AND DISCUSSION

The research data were obtained from the results of the critical thinking skills test. These results were subsequently analyzed to determine whether the use of PBL with a GeoGebra-assisted deep learning approach was effective in enhancing students' critical thinking skills. The analysis included a classical learning mastery test, an independent sample t-test, and a test of two proportions. Prior to the analysis, the data had to fulfill prerequisite tests, namely normality and homogeneity tests. The normality test was conducted to determine whether the research data were normally distributed. In this study, the normality test was performed on the pretest and posttest data of students' critical thinking skills for both the experimental and control groups using the Kolmogorov-Smirnov test, assisted by SPSS version 32 software. The results of the normality test for the critical thinking skills are presented in Table 1 below.

Table 1. Normality Test Results

	Kolmogorov-Smirnov		
	Statistic	**df**	**Sig.**
Pretest Experiment	0,131	32	0,174
Pretest Control	0,099	32	0,200
Pretest Experiment	0,137	32	0,135
Pretest Control	0,114	32	0,200

Based on the SPSS output for the Kolmogorov-Smirnov test, the significance value of the pretest data in the experimental group was $p = 0.174 > \alpha = 0.05$, and in the control group, it was $p = 0.200 >$

$\alpha = 0.05$. Furthermore, the significance value of the posttest data in the experimental group was $p = 0.135 > \alpha = 0.05$, and in the control group, it was $p = 0.200 > \alpha = 0.05$. Based on the testing criteria, H_0 was accepted. Therefore, the test score data originated from a normally distributed population. Subsequently, a homogeneity test was conducted to determine whether the data variances in the experimental and control groups were homogeneous or equal. In this study, the homogeneity test was performed on the students' critical thinking skills pretest and post-test data using Levene's Test, assisted by SPSS version 32 software. The results of the homogeneity test for the critical thinking skills are presented in Table 2 below.

Table 2. Homogeneity Test Results

		Levene Statistic	df1	df2	Sig.
Pretest	Based on Mean	1,316	1	62	0,256
Posttest	Based on Mean	2,765	1	62	0,256

Based on the SPSS output, the significance values (*Based on Mean*) for the pretest and posttest data were $p = 0.256 > \alpha = 0.05$ and $p = 0.101 > \alpha = 0.05$, respectively. Based on the testing criteria, H_0 was accepted. Thus, the test score data originated from populations with equal or homogeneous variances. The classical mastery test was used to examine whether students' critical thinking skills in PBL with a GeoGebra-assisted deep learning approach on the topic of straight-line equations achieved classical mastery; that is, the proportion of students who met the minimum mastery criteria (KKTP) exceeded 75%, with the threshold score set at 80. The test was conducted using a right-tailed one-proportion z-test. The results of the classical mastery proportion test are presented in Table 3 below.

Table 3. Classical Mastery Test Results

n	x	z_{count}	z_{table}
32	29	2,041	1,645

Since $z_{calculated} = 2.041 \geq z_{0.5-\alpha} = 1.645$, H_0 was rejected. Consequently, the proportion of students who achieved critical thinking skills mastery in the PBL with a GeoGebra-assisted deep learning approach on the topic of straight-line equations exceeded 0.75. The independent sample t-test was used to determine whether the average critical thinking skills of students in the PBL with a GeoGebra-assisted deep learning approach were higher than the average critical thinking skills of students in the standard PBL on the topic of straight-line equations. The testing was conducted using a one-tailed independent sample t-test. The results of the independent sample t-test are presented in Table 4 below.

Table 4. Independent Sample T-Test Results

$\overline{x_1}$	$\overline{x_2}$	t_{count}	t_{table}
86,250	73,125	6,006	1,670

Since $t_{calculated} = 6.006 > t_{(1-\alpha,df)} = 1.670$, H_0 was rejected. Consequently, the average critical thinking skills test score of students in the PBL with a GeoGebra-assisted deep learning approach was higher than the average score in the standard PBL on the topic of straight-line equations. A test of two proportions was used to determine whether the proportion of students achieving critical thinking skills mastery in the PBL with a GeoGebra-assisted deep learning approach was higher than the proportion in the standard PBL on the topic of straight-line equations. The testing was conducted using a two-proportion z-test. The results of the test of two proportions are presented in Table 5 below.

Table 5. Test of Two Proportions Results

x_1	x_2	z_{hitung}	z_{tabel}
29	10	4,867	1,645

Since $z_{calculated} = 4.867 \geq z_{0.5-\alpha} = 1.645$, H_0 was rejected. Consequently, the proportion of students who achieved mastery in the PBL with a GeoGebra-assisted deep learning approach group

was greater than the proportion of students who achieved mastery in the standard PBL group on the topic of straight-line equations. The research findings demonstrated that PBL with a GeoGebra-assisted deep learning approach was effective in improving students' critical thinking skills. This effectiveness was evidenced by the achievement of classical mastery, the increased average in critical thinking skills, and the higher proportion of students achieving mastery compared to the control group.

The effectiveness of this instruction was supported by the implementation of PBL through five learning phases, namely: problem orientation, organizing students for study, guiding investigations, developing and presenting results, and analyzing and evaluating the problem-solving process. These phases encouraged the development of students' critical thinking skills. The learning process was further reinforced by the application of a deep learning approach through the principles of mindful learning, meaningful learning, and joyful learning, which encouraged students to understand concepts profoundly, connect the materials with real-life experiences, and reflect on their learning processes. The use of GeoGebra helped visualize the concepts of straight-line equations dynamically, making it easier for students to connect algebraic and graphical representations, which ultimately supported the processes of analysis, evaluation, and problem-solving. Therefore, the implementation of PBL combined with a GeoGebra-assisted deep learning approach has been proven effective in enhancing students' critical thinking skills.

CONCLUSION

Based on the results and discussion, it can be concluded that the implementation of PBL with a GeoGebra-assisted deep learning approach is effective in improving students' critical thinking skills. This effectiveness is evidenced by the achievement of classical mastery, a higher average in critical thinking skills, and a greater proportion of learning mastery in the experimental group compared to the control group. Thus, the integration of PBL with a GeoGebra-assisted deep learning approach can serve as an alternative mathematics instructional strategy to develop students' critical thinking skills.

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