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EFFECTIVENESS OF THE DEEP LEARNING APPROACH IN ENHANCING STUDENTS' CRITICAL THINKING SKILLS ON MATRIX MATERIAL

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Abstract

This study investigates the effectiveness of the Deep Learning approach in enhancing students' critical thinking skills in matrix material. The approach emphasizes deep understanding, enabling students to analyze, interpret, and connect concepts comprehensively. A quasi-experimental design with a nonequivalent control group was employed, involving tenth-grade students at Muhammadiyah Kalasan Senior High School. The research sample consisted of two classes: the experimental class (X-A), which applied the Deep Learning approach, and the control class (X-B), which used conventional teaching methods, with 28 students in each group. To evaluate learning improvement, both groups took a pretest before treatment and a posttest afterward. Data analysis utilized an independent sample t-test to test the hypothesis and an n-Gain test to assess critical thinking skill improvement. Results indicated a significant increase in students' critical thinking abilities, with the experimental group outperforming the control group (sig. 0.000 < 0.05). The highest improvement was in the Situation aspect (56.43), while the Overview aspect showed the least growth (6.43). The average score increased from 55.71 to 86.18, with an N-Gain of 0.68 (moderate category). Further research could explore this approach in different subjects to enhance educational quality.

1. INTRODUCTION

Mathematics education plays a crucial role in developing students' logical, analytical, and critical thinking skills (Fernando et al., 2023). One of the topics that often pose challenges for students is matrices due to their abstract nature and extensive applications across various disciplines, including economics, engineering, and computer science. Despite its high relevance to real-world scenarios, many students struggle to comprehend matrix operations, determinants, and inverses in depth (Handayani, 2021). This difficulty arises from conventional teaching approaches that are often procedural, lacking emphasis on deep conceptual understanding. Therefore, a more effective approach is needed to enhance students' comprehension while simultaneously fostering their critical thinking skills.

The Deep Learning approach in education is not merely about utilizing artificial intelligence technology but rather a learning strategy that prioritizes deep understanding over rote memorization and mechanical application (Agyeman, 2024). In the context of mathematics learning, this approach encourages students to explore concepts more deeply, connect different ideas, and develop a reflective mindset when solving problems. It also incorporates strategies such as inquiry-based learning, problem-solving, and reflective discussions, all of which can enhance students' conceptual understanding of matrices while developing their critical thinking skills.

Critical thinking is an essential skill for students to navigate the challenges of the 21st century (Azzahra et al., 2023; Mukarima et al., 2024). According to Siswanto & Andriyani (2024), critical thinking involves the ability to analyze problems, evaluate information objectively, and make rational decisions based on evidence. In matrix learning, critical thinking can be demonstrated through problem-solving activities that require data interpretation, proof of matrix properties, and exploration of relationships between matrices and real-world phenomena. If students merely memorize formulas without understanding the underlying concepts, they will struggle to apply them in more complex contexts. Therefore, a teaching strategy that trains students to think more deeply and systematically is essential.

Previous studies have shown that learning approaches emphasizing deep understanding are more effective in enhancing conceptual comprehension than conventional methods. For instance, research by Aziz & Zakir (2025) highlights that Deep Learning improves analytical and synthesis skills in mathematics learning. Another study by Adnyana (2024) found that students who learn using a deep learning approach tend to better connect learned concepts with their experiences, leading to improved long-term retention and conceptual understanding. These findings suggest that this approach holds potential for application in matrix learning to enhance students' critical thinking abilities.

In Indonesia, the implementation of the Kurikulum Merdeka provides greater flexibility for learning innovations that emphasize problem-solving and critical thinking (Rahayu et al., 2022). However, in practice, many teachers still rely on lecture-based expository methods, resulting in one-way learning that lacks active student engagement. In matrix learning, exploring concepts and their real-life applications is crucial for developing a deeper understanding. Therefore, this study aims to examine the effectiveness of the Deep Learning approach in enhancing the critical thinking skills of eleventh-grade students in matrix material.

Moreover, this study considers several factors that may influence the effectiveness of the Deep Learning approach, such as teachers' readiness to implement this strategy, students' engagement in active learning, and the availability of adequate learning resources. The implementation of this approach follows a structured process that includes problem exploration, in-depth investigation, reflection, and real-world application (Bintang & Imaduddin, 2024). Thus, it is expected that this approach will not

only improve students' learning outcomes but also equip them with critical thinking skills applicable to various fields of life.

By focusing on the effectiveness of the Deep Learning approach, this study aims to provide deeper insights into how conceptual understanding-based learning strategies can help students develop critical thinking skills. Additionally, it seeks to explore how this approach can be integrated into mathematics teaching practices in schools. The findings of this research are expected to contribute to the advancement of innovative learning strategies that foster deeper student engagement, enhance conceptual mastery, and ultimately prepare students to tackle complex real-world problems.

2. METHOD

This study employs a quasi-experimental design to examine the effectiveness of the Deep Learning approach in enhancing the critical thinking skills of 10th-grade students on the topic of matrices. The study was conducted at Muhammadiyah Kalasan Senior High School from January to February 2025, involving two classes as research samples: Class X-A as the experimental group and Class X-B as the control group, each consisting of 28 students.

The research follows a nonequivalent control group design, beginning with a pretest for both groups to measure students' initial abilities before the intervention. The test instrument used had been previously tested in Class XI-A and was deemed valid and reliable. The test consisted of six questions designed to assess six indicators of critical thinking skills based on Ennis (1993): focus, reason, inference, situation, clarity, and overview.

Following the pretest, the experimental group received instruction using the Deep Learning approach, while the control group continued with the conventional teaching methods typically employed by teachers. After the intervention, a posttest was administered to both groups to evaluate differences in students' learning outcomes in the matrix material. The research data were analyzed using quantitative statistical techniques, specifically the independent sample t-test to test the hypothesis and the n-Gain test based on Hake (1999) to measure the improvement in students' critical thinking skills after the learning intervention.

3. RESULTS AND DISCUSSION

Results

Before conducting the research, the researcher prepared a test instrument which was then tested first in class XII Natural Sciences. After getting the results, the validity and reliability are then tested. The calculation results are assisted using SPSS-25 as follows.

Table 1. Validity and Reliability Test Results

No	Validity (r_{table}= 0,374)		Reliability (*Cronbach's Alpha*)	
	R_{count}	Criteria	Value	Criteria
1	0,473	Valid	0,628	Reliabel
2	0,732	Valid		
3	0,512	Valid		
4	0,470	Valid		
5	0,762	Valid		
6	0,583	Valid		

Based on the table above, it can be seen that all the question numbers received a Pearson Correlation value $t_{count} > t_{table}$ (0.321) and a Cronbach's Alpha value of 0.628 > 0.05, so it can be said that all the question numbers are valid and reliable. After the test instrument was said to be valid and reliable, the researcher then conducted a pretest in the experimental and control classes, then the test results were tested for normality and homogeneity. The results of the normality test can be seen in the following table.

Table 2. Normality Test Results

Class	Shapiro-Wilk		
	Statistic	df	Sig.
Control	.964	28	.439
Experimental	.949	28	.191

Based on the table above, it can be seen that the results of the Shapiro-Wilk normality test with a value of sig. > 0.05 in the control class 0.439 and experimental 0.191. Based on this, it can be said that the two classes have a

normal distribution. Next, homogeneity will be tested. The homogeneity test results can be seen in the following table.

Table 3. Homogeneity Test Results

Nilai	Levene Statistic	df1	df2	Sig.
Based on Mean	.797	1	54	.376
Based on Median	.627	1	54	.432
Based on Median and with adjusted df	.627	1	52.26	.432
Based on trimmed mean	.778	1	54	.382

Based on the table above, it can be seen that the sig. from based on mean, namely 0.376 > 0.05. It can be said that the two data are homogeneous. After the two classes are said to be normal and homogeneous, the hypothesis will then be tested using the independent sample t-test, with the following results.

Table 4. Independent sample t-test results

Value	t-test for Equality of Means						
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Equal variances assumed	4.55	54	.000	1083.17	237.57	606.86	1559.49
Equal variances not assumed	4.55	50.22	.000	1083.17	237.57	606.04	1560.31

Based on the table above, it can be seen that the sig (2-tailed) value is 0.000 < 0.05, which shows that the Deep Learning approach is effective in students' critical thinking abilities in matrix material. The increase in each indicator of critical thinking can be seen in the following picture

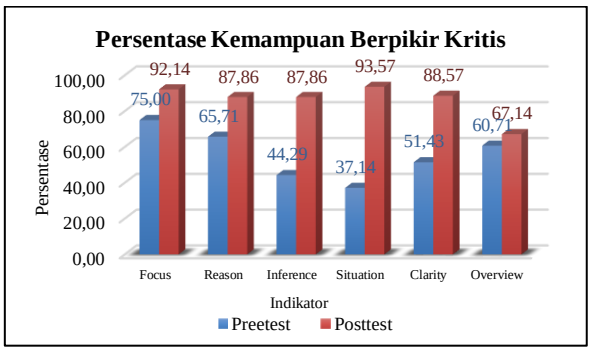

Figure 1. Percentage of Critical Thinking Ability

Based on the results of the analysis, there was an increase in scores for each indicator after being given treatment. The Focus indicator increased from 75.00 in the pretest to 92.14 in the posttest with a difference of 17.14. The Reason indicator increased from 65.71 to 87.86 with a difference of 22.14. The Inference indicator experienced a significant increase, namely from 44.29 to 87.86 with a difference of 43.57. The Situation indicator showed the highest increase, from 37.14 on the pretest to 93.57 on the posttest with a difference of 56.43. Meanwhile, the Clarity indicator increased from 51.43 to 88.57 with a difference of 37.14, and the Overview indicator experienced the smallest increase, namely from 60.71 to 67.14 with a difference of 6.43. As well as the learning achievements of experimental class students on matrix material can be seen in the following figure.

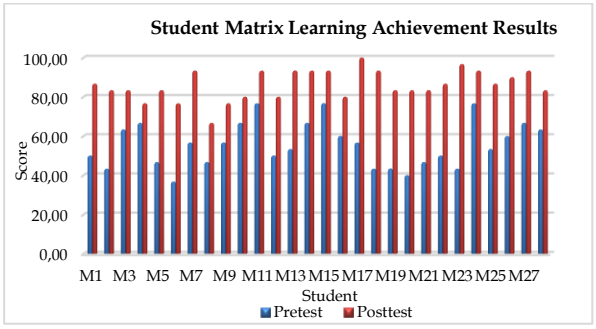

Figure 2. Student Matrix Learning Achievement Results

Based on the picture above, descriptive analysis of the number of participants in this study was 28 people. At the pretest stage, the minimum score obtained was 36.67, while the maximum score reached 76.67, with a total score of 156,002 and an average of 55.71. After being given treatment, the posttest results showed an improvement with a minimum score of 66.67 and a maximum score of 100. The total number of posttest scores was 241,331 with an average of 86.18. Next, an n-Gain test was carried out to determine the increase in students' critical thinking skills with the following calculations.

$$\langle g \rangle = \frac{S_{post} - S_{pre}}{SMI - S_{pre}} = \frac{86{,}18 - 55{,}71}{100 - 55{,}71} = \frac{30{,}47}{44{,}29} = 0{,}68$$

From the calculation results above, it shows that the average pretest and posttest

value in the N-Gain calculation is 0.68. So it can be said that there is an increase in critical thinking skills in the moderate category.

Discussion

Based on the research findings, the validity and reliability tests of the test instrument indicated that all question items met the criteria for validity and reliability. The validity test using SPSS-25 showed that each question item had a Pearson Correlation value where $t_{count} > t_{table}$ (0.321), categorizing the items as valid. Additionally, the Cronbach's Alpha value of 0.628 indicated that the instrument had a fairly good level of reliability.

After confirming the instrument's validity and reliability, normality and homogeneity tests were conducted to ensure that the data met the assumption of normal distribution and had homogeneous variance. The normality test using the Shapiro-Wilk method showed that the significance values for the control group (0.439) and the experimental group (0.191) were both greater than 0.05, indicating that the data were normally distributed. Similarly, the homogeneity test using Levene's Test showed a significance value of 0.376, which was greater than 0.05, confirming that both groups had equal variance.

Subsequently, a hypothesis test was conducted using an independent sample t-test to determine the effectiveness of the Deep Learning approach in enhancing students' critical thinking skills on matrix material. The results showed a significance value (2-tailed) of 0.000, which was less than 0.05, indicating a significant difference between the experimental and control groups after the intervention. These findings align with the study conducted by Aziz & Zakir (2025) which stated that the Deep Learning approach enhances students' critical thinking skills by encouraging in-depth exploration and better conceptual understanding.

Further analysis of critical thinking indicators revealed a significant improvement following the implementation of the Deep Learning approach. The Situation indicator showed the highest increase of 56.43 points, while the Overview indicator exhibited the smallest increase of 6.43 points. This finding suggests that the Deep Learning approach is more effective in improving situational analysis skills compared to the ability to summarize overall concepts. These results are consistent with the studies conducted by Afifah & Kusuma (2021), Rismayanti et al. (2022) and Utami (2022), which stated that critical thinking involves more complex analytical skills and requires intensive practice to improve significantly.

Additionally, students' academic performance also showed a significant improvement after the intervention. The average pretest score of 55.71 increased to 86.18 in the posttest, with the minimum score rising from 36.67 to 66.67 and the maximum score from 76.67 to 100. This result was further supported by an N-Gain calculation of 0.68, indicating a moderate level of improvement. These findings reinforce the studies conducted by Azis et al. (2025), Hariyanti (2024) and Herliani (2025), which concluded that the Deep Learning approach significantly enhances students' conceptual understanding and learning outcomes.

Overall, the results of this study demonstrate that the Deep Learning approach is highly effective in improving students' critical thinking skills in matrix material. The significant improvement across all critical thinking indicators suggests that this teaching strategy successfully encourages students to think more analytically, reflectively, and logically when solving mathematical problems. This conclusion is further supported by research conducted by Adna et al. (2022), Farohi & Parhan (2024) and Fauziyah et al. (2024), which emphasized that learning based on deeper information processing helps students connect previously learned concepts with real-world experiences.

Thus, this study makes a significant contribution to the field of education, particularly in the development of

instructional strategies that enhance students' critical thinking skills. The findings suggest that the Deep Learning approach can serve as an effective alternative in mathematics education, particularly for teaching concepts that require deep understanding and critical analysis. Therefore, further research can be conducted to explore how this approach can be applied in various learning contexts to improve the overall quality of education.

4. CONCLUSION

Based on research results, the Deep Learning approach has proven to be effective in improving students' critical thinking skills in matrix material. Testing the validity and reliability of the instrument shows that the questions used meet the valid and reliable criteria. The research data also meets the assumptions of normal and homogeneous distribution, so that the analysis results can be trusted. The results of the independent sample t-test showed that there was a significant difference between the experimental and control groups after being given treatment, with a significance value of 0.000 <0.05. The significant increase in critical thinking indicators was mainly seen in the Situation aspect (56.43), while the Overview aspect experienced the smallest increase (6.43). In addition, the students' average score increased from 55.71 (pretest) to 86.18 (posttest) with an N-Gain of 0.68 (medium category), which shows a significant increase in students' critical thinking abilities. Further research can be conducted to develop the application of this strategy in various learning contexts to improve the overall quality of education.

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