Al-Ishlah: Jurnal Pendidikan
Vol.17, 3 (September 2025), p. 5673-5682
ISSN: 2087-9490 EISSN: 2597-940X, DOI: 10.35445/alishlah.v17i3. 6879

The Effectiveness of Differentiated Learning on Critical Thinking Skills and Student Activeness in Mathematics Learning

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ARTICLE INFORMATION

Keywords

differentiated learning;
critical thinking skills;
activeness;
mathematics

Article history:

Accepted 2025-01-10
Revised 2025-03-12
Accepted 2025-09-30

ABSTRACT

This study aimed to examine the effectiveness of differentiated learning in enhancing critical thinking skills and student activeness in mathematics among fourth-grade students in public elementary schools in the Trucuk District, Klaten. Differentiated learning is designed to address diverse student needs, interests, and abilities through tailored content, process, and assessment strategies. A quasi-experimental design was employed, involving 70 students from four randomly selected schools. Two schools were assigned as experimental groups implementing differentiated learning, while the remaining two served as control groups using conventional teaching methods. Data were collected through critical thinking tests and observation sheets measuring student activeness. Statistical analyses included descriptive statistics, classical assumption tests, and hypothesis testing using paired t-tests. The findings revealed a statistically significant difference between the experimental and control groups. Students in the experimental group demonstrated higher critical thinking scores (mean = 54.20) than those in the control group (mean = 42.83), with a t-value of 17.717 and a p-value of 0.000 ($p < 0.05$). Similarly, student activeness improved significantly in the experimental group (mean = 53.34) compared to the control group (mean = 43.51), supported by a t-value of 6.254 and a p-value of 0.000. The results suggest that differentiated learning effectively enhances both critical thinking and student activeness in mathematics. Individualized instruction provides meaningful engagement and supports cognitive development, particularly in elementary education. This study highlights the importance of responsive teaching strategies in fostering student-centered learning environments.

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1. INTRODUCTION

Mathematics teaching is a series of exchanges between various learning components to develop students' problem-solving thinking skills. Students are expected to develop various mathematical concepts through the mathematics learning process. Through mathematics learning, students are encouraged to actively participate in question-and-answer sessions and discussions, thereby developing

their mathematical competencies and skills. The use of various learning models, strategies, and methods is tailored to the material's needs and the students' specific circumstances. (Gusteti & Neviryani, 2022) .

Mathematics lessons contain complex conceptual understanding, including various formulas that must be memorized, calculations, and problem solving that involve complex thinking processes. Understanding of mathematical concepts can be achieved optimally if the learning carried out by teachers is fun and meaningful. Firdaus, Afianti, Cahya, & Septianingtias (2022) . The concept of mathematics learning that applies the instillation of values by providing examples (ing ngarso sung tulodo), fostering the will (ing madyo mangun karso), and encouraging student creativity in teaching and learning activities (tut wuri handayani) is a manifestation of the teaching and learning concept put forward by Ki Hajar Dewantara. Therefore, the role of a teacher is how to create learning that favors students, namely a learning condition where students are given the freedom to think and build their potential, so that students are able to grow and develop according to their nature. The philosophical foundation of education conveyed by Ki Hajar Dewantara is in line with the idea of differentiated learning (Wahyuni, 2020) .

Differentiated learning is an approach that recognizes and accommodates the diverse needs, interests, and learning preferences of students to improve learning outcomes. As Nurrawi et al. (2023) argue, it is a form of adaptation to these differences, aiming to support each student in achieving optimal academic performance. Furthermore, Marlina and Avandra (2019) emphasize that differentiated learning should not be understood as individualized instruction for each student, but rather as an approach that addresses various student needs through independent learning and by maximizing learning opportunities. To implement this approach effectively, teachers must design instruction that incorporates multiple strategies, methods, media, and assessments. However, classroom management becomes a significant challenge, as students possess varied learning styles and requirements. Through the application of differentiated learning, teachers can better support students in developing critical thinking skills.

Critical thinking skills are one of the 21st Century Learning skills, along with other skills such as reading, writing, science, and mathematics (Noviyanti, N., Yuniarti, Y., & Lestari, 2023). Critical thinking skills are essential for solving mathematical problems. Mathematics teaches students to make decisions and draw conclusions based on reasoned, rational, critical, careful, effective, and efficient thinking. Therefore, the need for critical thinking skills is closely related to everyday life which is dynamic, rapidly changing, and unpredictable. (Jayadipura, 2018) .

Critical thinking skills and integrated learning are closely related. Research conducted by (Pane, 2022) showed an increase in elementary school students' critical thinking skills through differentiated learning. Meanwhile, a study by Bell, Tannenbaum, Ford, Noe, & Kraiger (2017) , found a big difference between the critical thinking and problem-solving skills of students in a control class that used a teacher-centered learning model and those in an experimental class that used differentiated learning. The findings indicated that students in the experimental class achieved higher average scores, so suggesting that participants in differentiated learning exhibited superior problem-solving and critical thinking abilities compared to those engaged in traditional learning.

Furthermore, differentiated learning is also related to student activity. Research (Ni'mah, Prayito, Sulianto, & Darsino, 2023) shows that differentiated learning can increase student activity by 92-96% in activity indicators, namely when students try to solve problems or questions given, students actively participate in group discussions based on teacher guidance. This is also supported by research (Erotocritou, 2020), which demonstrates that differentiated instruction may boost each student's awareness and engagement in the classroom. Differentiated project-based learning has been shown to improve student perspectives, encourage self-identification, and motivate students to participate in activities they find unpleasant (Amaliyah et al., 2023).

Based on the results of the researcher's initial observations conducted on fourth-grade students of SD Negeri 1 Karangpakel, it was discovered that there were problems in the field in mathematics learning.

Some of these things include: student activities appear passive because they only sit quietly and listen (70.59%). In addition, student activities that ask questions or express opinions are also very rare, namely only 5 students (29.4%). Even if the teacher asks, they tend to look down and do not want to answer (88.3%). So in general it can be concluded that students' thinking skills are included in the low criteria so that this also has an impact on student learning outcomes.

Empirical data shows that the average value of the Mathematics Daily Test for fourth grade students is 70.6, still below the Mathematics KKTP of 75. Of the 17 fourth grade students, only 7 students or 41.2% achieved the KKTP. According to (Trianto., 2019: 241) , a class is considered classically complete if at least 85% of the pupils have finished their coursework. The aforementioned data demonstrates that fourth-grade pupils' learning results in mathematics are categorized as poor, as they fall short of classical completeness. The most common example in mathematics learning, the average data for fourth-grade students' scores which only reached 70.6, is often used as a general illustration that not all students have not achieved learning completeness, even though in reality, there are some students who have achieved the KKTP.

Therefore, differentiated learning is important to implement so that all students with diverse thinking abilities are involved in a learning environment that is fun, challenging, and meaningful for all students. Teachers, besides being learning resources, also play a role as managers and facilitators of learning. In this instance, educators must choose suitable learning stimuli and media that align with the characteristics and learning preferences of students to cultivate critical thinking abilities (Agnafia, 2019) . The aim of differentiated learning is to provide instruction tailored to student need. (Ubabuddin, Nasikhah, & Subowo, 2021) stated that differentiated learning allows each teacher to meet directly and interact directly with students at a level appropriate to their level of knowledge to prepare their learning preferences.

The term "differentiated learning" describes a set of choices made by educators based on the unique needs of each learner. These decisions' characteristics include: 1) establishing learning environments that encourage students to perform at a high level; 2) addressing the various learning needs of students through lesson plans, learning materials, learning media, learning strategies, assignments, and assessments; and 3) organizing (managing) an efficient classroom through procedures and routines that offer flexibility with a clear structure, ensuring that learning can proceed smoothly even with a variety of activities. In 2021, Suwartiningsih. According to the foregoing backdrop, this research aims to examine how varied instruction affects fourth-grade students' critical thinking abilities and level of activity at public elementary schools in the Trucuk District of the Klaten Regency.

The novelty of this research is its focus on the systematic application of differentiated learning in mathematics in fourth-grade elementary school. Previously, differentiated learning was primarily studied in the context of inclusive learning or secondary education, resulting in limited application at the elementary level, particularly in mathematics.

2. METHOD

This study uses a quantitative data analysis technique in conjunction with a quasi-experimental design. To guarantee that study circumstances can be properly controlled, experimental research is implemented in a methodical, logical, and exact way. According to Sugiyono (2019) , experimental research is a technique used to investigate how certain treatments affect other variables under carefully monitored conditions. The current research was conducted at public elementary schools in Klaten Regency's Trucuk District, with a focus on mathematics courses for fourth graders in each participating school. All fourth-graders from the Trucuk District's public elementary schools, totaling 526 pupils spread over 31 schools, were included in the study population. This study's primary goal is to investigate how well varied instruction might improve students' critical thinking abilities and level of engagement during math classes in the fourth grade in public elementary schools in the Trucuk District of Klaten.

The sample included 4 schools, with 2 schools as control classes and 2 schools as experimental classes. The sampling technique applied in this study was the Random Sampling technique. During the study, there were 2 control classes taught using conventional methods and 2 experimental classes taught using differentiated learning. The data used in this study were obtained through tests to determine students' mathematics learning outcomes and observations to obtain data on student learning activities. The collected data were analyzed using descriptive analysis consisting of mean, variance, and standard deviation. The results of the study that have met the prerequisites are the normality test with the selection of the Kolmogorov-Smirnov test with a sig. Value > 0.05, and the homogeneity test using the Levene test with a sig. Value > 0.05. The hypothesis was tested using a correlated t-test.

3. FINDINGS AND DISCUSSION

3.1 Results

3.1.1 Descriptive Analysis

The following table shows a descriptive analysis of learning outcome factors, critical thinking abilities, and student activities based on the mean, standard deviation, maximum, and minimum.

Table 1. Descriptive Analysis Results

Variables	Aspect	Experimental Class	Control Class
Learning outcomes	*Method*	7.99	6.29
	Standard Deviation	0.80	1.56
	Maximum	10.0	9.5
	Minimum	7.0	3.0
Critical thinking skills	*Method*	54.20	42.83
	Standard Deviation	7.95	3.00
	Maximum	66.0	48.0
	Minimum	23.0	36.0
Student Activities	*Method*	53.34	43.51
	Standard Deviation	8.27	2.51
	Maximum	75.0	48.0
	Minimum	25.0	39.0

Source: Results of data processing in 2024

The table shows that the experimental class's learning outcome variable had an average score of 7.99 and a standard deviation of 0.80. The highest score was 10.0 while the lowest was 7.0. In contrast, the control class has an average of 6.29, a standard deviation of 1.56; the range is 9.5 at the highest and 3.0 at the lowest. A maximum score of 66.0 and a minimum score of 23.1 were shown on the experimental class's critical thinking skills variable, which had an average score of 54.20 and a standard deviation of 7.95. Contrarily, the control group stands at 42.83 on average, with a standard deviation of 3.00. The highest score is 48.0, while the lowest is 36.0. The student activity variable in the experimental class indicates an average of 53.34, a standard deviation of 8.27, with the highest score at 75.0 and the lowest at 25.0. In comparison, the control class presents an average of 45.31, supported by a standard deviation of 2.51, with a maximum of 48.0 and a minimum of 39.0.

3.1.2 Classical assumption test

1) Normality test

The Kolmogorov-Smirnov test for normalcy in this study found a value of 0.075, which is higher than the sig. (p-value > 0.05). This shows that all research data used as samples followed a normal distribution.

2) Homogeneity Test

The SPSS software is used to analyze the Test of Homogeneity of Variance in order to perform homogeneity testing. If the probability (Sig) is more than 0.05, the data is considered homogenous; if it is less than 0.05, the data is not. To ascertain whether or not learning outcome data, critical thinking abilities, and student activities are homogenous, homogeneity testing is performed. The learning outcome variable data's homogeneity test yielded a sig result. A 0.082 value indicates sig. It may be concluded that the learning outcome variable data is homogenous since this value is more than the sig. level of 0.05 (0.082 > 0.05). According to the preceding data, the critical thinking skills variable's homogeneity test yields a sig value of 0.106. This number suggests that the data on the critical thinking abilities variable is homogenous since it above the sig. Threshold of 0.05 (0.106 > 0.05). Based on the information in the preceding table, the student activity variable's homogeneity test yielded a sig value of 0.074. The student activity variable data may be inferred as homogenous since this result (0.074 > 0.05) is greater than the 0.05 sig. threshold.

3) Autocorrelation Test

An autocorrelation test aims to examine whether residual errors in a given period are correlated with residual errors from the preceding period (t-1) within a linear regression framework. In this research, the autocorrelation examination was carried out through the s-test method assisted by the SPSS application. The Run test, categorized under nonparametric statistics, is applied to assess whether residuals exhibit a significant correlation level or not. The outcome of the autocorrelation analysis revealed an Asymp.Sig. (2-tailed) value of 0.054, which surpasses the standard sig. threshold of 0.05. This result suggests that the dataset is adequately random, thereby confirming that no autocorrelation issue exists within the analyzed data.

4) Heteroscedasticity Test

The purpose of the heteroscedasticity test is to identify regression models that may not adhere to classical principles. Heteroscedasticity occurs when there is a discrepancy between the data points in terms of the variance of the residuals in the regression equation. This research checked for heteroscedasticity using the Glejser Test. The Glejser Test is carried out by putting the independent variables into a regression with the absolute residual values. At a confidence level below 5%, heteroscedasticity is inferred when an independent variable significantly affects the dependent variable.

Results from data processing indicated that all variables included in the regression model used for this study had sig. values greater than or equal to 0.05, or the 5% threshold. A result of 0.248 indicates strong critical thinking abilities, while a value of 0.869 indicates strong student engagement. All of the p-values are more than 0.05, therefore it seems that the regression model variables aren't heteroscedastic.

5) Hypothesis Testing

Cognitive learning outcomes, learning independence, and student engagement are the dependent variables of the research. The t-test is designed to investigate the impact of the independent variable, which is the application of differentiated learning, on these variables. In addition, by analyzing the sign of the regression coefficient, the t-test may be used to determine the direction of the independent variable's influence on the dependent variable. By keeping an eye on the probability value (sig)-t, the testing procedure is carried out. If the sig-t value is less than 0.05 (sig-t < 0.05), which is less than 5%, it may be concluded that the independent variable has a substantial impact on the dependent variable. Therefore, the suggested hypothesis can be accepted. However, the null hypothesis is rejected if the sig-t value is more than 0.05, which is equal to 5%. This indicates that the independent variable does

not significantly affect the dependent variable. The following section presents the outcomes of the t-test performed on the research data.

The following findings were derived from the t-test assessing the impact of varied instruction on student activities and critical thinking abilities.

1. Impact on the ability to think critically
   The t-value for critical thinking ability is 5.818 and it is more than the t-table value of 1.6909. This is due to the fact that the sig. threshold (sig. 2-tailed) is 0.000, which is lower than 0.05 (0.000 < 0.05), therefore accepting Ha and rejecting H0. Individualized education has a significant influence on pupils' critical thinking ability, as shown by this outcome.
2. Impact on the actions of students
   In addition to being higher than the t-table value of 1.6909 (t-value > t-table), the t-value for student activity is 6.254. H0 is rejected while Ha is accepted because the sig. level (sig. 2-tailed) is 0.000, which is less than 0.05 (0.000 < 0.05). This suggests that student engagement is significantly impacted by differentiated instruction.
3. Critical thinking abilities' efficacy after tailored instruction
   The experimental class's mean score for critical thinking abilities was 54.20, higher than the 42.83 score of the control group. This outcome demonstrates how well differentiated instruction is.
4. The success of student activities after individualized instruction
   The experimental class's average score on student activities was 53.34, higher than the 43.51 score of the control group. This result shows that improving student activities via differentiated instruction is successful.
5. The F exam
   Results from the F test show that differentiated learning has a significant effect on students' critical thinking skills and activities, as the calculated F value is higher than the F table (F table = 3.305).

The F test was used in this study to investigate how individualized instruction affected student involvement, critical thinking skills, and learning outcomes. Referring to the F test results presented in the table, it can be inferred that differentiated learning exerts a significant influence on all three variables. First, the obtained F value for learning outcomes, which is 32.789, exceeds the F table value of 3.305 (F calculated > F table) with a sig. level of 0.000, demonstrating that differentiated learning significantly affects student learning outcomes. Second, the F value for critical thinking skills, amounting to 62.639, is also higher than the F table value of 3.305 (F calculated > F table) with a sig. value of 0.000, signifying a substantial impact on students' critical thinking abilities. Third, the F value for student participation, which is 45.247, surpasses the F table value of 3.305 (F calculated > F table) with a sig. value of 0.000, indicating that differentiated learning meaningfully affects student activities. Therefore, the findings of the F test affirm that differentiated learning has a noteworthy effect on learning outcomes, critical thinking skills, and student participation.

3.2 Discussion

3.2.1 The Effect of Differentiated Learning on Student Learning Outcomes

A comprehensive analysis of the causes of low student learning outcomes is necessary to determine whether the underlying factors have been addressed**.** Low learning outcomes, particularly pretest scores, can be caused by various factors such as a lack of motivation to learn, learning methods that are less suited to students' needs, a poor understanding of basic mathematical concepts, or a lack of differentiated learning strategies. Therefore, after implementing differentiated learning, it is important to conduct a follow-up evaluation to ensure that the underlying causes of low learning outcomes have been addressed. If not, then continuous improvement in the learning strategies used is necessary.

Based on the analysis that has been done, the learning outcome variable has a value of -5.818. This negative value occurs because the average pretest learning outcome is lower than the average posttest. In a situation like this, a negative t-value is interpreted as positive, so the t-value becomes 5.818. Considering that the t-table value on df 34 is 1.6909, it is clear that the t-table value (5.818) is greater. In addition, with a 0.000 sig. value (sig. 2-tailed), which is less than the 0.05 criterion, the results are not significant. Students' learning results are affected by differentiated teaching, as Ha is accepted and H0 is denied.

These findings align with the study conducted by Linda et al. (2021), which demonstrated that the implementation of differentiated learning in Cycle II led to significant improvements compared to Cycle I. The proportion of students achieving the Minimum Competency Criteria (KKM) increased from 51.72% to 96.55%, while the average student score rose from 66.55 in Cycle I to 80 in Cycle II. The study also revealed that differentiated instruction positively influenced student learning activity and engagement. Similarly, research by Ibrahim, Zulkafli, Shah, and Amran (2017) found that differentiated learning strategies in Indonesian language instruction effectively addressed students' learning styles, interests, content preferences, learning processes, and final products. Their study showed that 72% of students demonstrated proficiency in product differentiation, and 92% reported feeling enthusiastic during the learning process.

Further supporting evidence is provided by Attin, Miranti, Pangesthi, and Dewi (2023), who emphasized that active learning plays a critical role in enhancing student motivation and engagement. Bulo (2024) also highlighted the importance of student activity in reinforcing understanding of mathematical concepts. In addition, Mulyasa and Aryani (2022) concluded that the integration of contextual approaches, such as Culturally Responsive Teaching (CRT), can significantly improve student learning outcomes.

3.2.2 The Effectiveness of Differentiated Learning on Students' Critical Thinking Skills

The results of this study show that critical thinking abilities are an important variable. A negative t-count of -7.717 was changed to a positive 7.717 due to the fact that the two groups' means were different. The t-table value of 1.6909 at df 34 indicates that the t-count (7.717) significantly surpasses the t-table value. In addition, because the significance threshold (sig. 2-tailed) is less than 0.05 (0.000 < 0.05), the null hypothesis (H0) is rejected and the alternative hypothesis (Ha) is accepted.

This finding provides strong evidence that individualized education has a substantial effect on pupils' capacity for critical thinking. The data also reveal that the control group scored 42.83% on the critical thinking skills test, whereas the experimental group averaged 54.20%. This outcome is consistent with research by Avandra (2022), which showed that students' critical thinking skills improved from cycle I to cycle II, with the percentage of students classified as "good" rising dramatically from 30% to 95%. Research (Mustadi, A., & Oktari, 2024) also emphasized that critical thinking skills are needed to understand various material concepts and solve learning problems, thus supporting the importance of implementing differentiated learning.

3.2.3 The Effectiveness of Differentiated Learning on Student Activeness

Differentiated learning in mathematics is implemented by adapting the content, process, and learning products to suit students' needs and abilities. In terms of content, teachers provide materials with varying levels of difficulty; for example, practice questions are differentiated based on students' ability levels (easy, medium, or difficult). In terms of process, teachers employ a variety of strategies, such as heterogeneous group discussions, the use of visual media, and more intensive guidance for students experiencing difficulties. In terms of product, students are given the freedom to demonstrate their understanding in various ways, such as re-explaining concepts in their own words, creating concept maps, or solving story problems. Through this differentiation, students are more actively involved, both in asking questions, discussing, and completing assignments according to their learning styles and abilities.

The results of the study showed that the student activity variable had a value of -6.254 which changed to positive (6.254) because the average activity of control class students was lower than the experimental class. With a t-table value of 1.6909 on df 34, the calculated t (6.254) was greater than the t-table (1.6909). The sig. value (sig. 2-tailed) of 0.000 was smaller than 0.05 (0.000 < 0.05) so that H0 was rejected and Ha was accepted. This indicates that differentiated learning has a significant influence on student activity. The results of the instrument validity were tested using content validity through expert judgment from mathematics education expert lecturers and elementary school teacher practitioners to ensure the suitability of the test items and observation indicators with the competencies being measured. In addition, the empirical validity test was carried out using Pearson Product Moment correlation analysis, where instrument items that had a correlation value above r table were declared valid.

Meanwhile, the instrument's reliability was tested using the Cronbach's Alpha coefficient. The calculation results showed that the learning outcome test's reliability value was in the high category (α > 0.70), while the student activity observation sheet also had a good reliability coefficient (α > 0.70). This indicates that the instrument used in the study was appropriate and consistent for measuring critical thinking skills, learning outcomes, and student engagement in mathematics learning.

Compared to the control group, the experimental group's students were more actively engaged (53.34). The use of diversified learning strategies in science classrooms has been shown to improve student engagement and retention of material (Jimry, 2020). Other research (Caron & Markusen, 2016) highlights that student activity can be enhanced through the application of relevant learning methods and media based on student characteristics. This reinforces the importance of an integrated learning approach in creating an effective and engaging learning environment.

4. CONCLUSION

This study concludes that differentiated learning is effective in enhancing students' critical thinking skills and increasing engagement during the learning process. By addressing individual differences in needs, interests, and abilities, this approach positively influenced both individual and group learning outcomes. Notably, fourth-grade students in the Trucuk District of Klaten demonstrated significant improvements in mathematical critical thinking and overall academic performance. However, the study has several limitations: it focused solely on mathematics, involved a relatively small sample (70 students from four schools), and was conducted over a short period, limiting the generalizability and the ability to assess long-term impacts. Future research should address these limitations by involving larger and more diverse samples, applying differentiated instruction across various subjects, conducting longitudinal studies to assess sustainability, and utilizing more varied assessment tools to explore critical thinking and student engagement in greater depth.

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