



Implementation of Differentiated Learning on Mathematical Critical Thinking Ability

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Abstract

This research focuses on the differences in mathematical critical thinking skills between students using differentiated learning strategies and undifferentiated learning strategies. The methodology used in this research is experimental research using the nonequivalent posttest-only control group design. The participants of this study consisted of X-1 and X-3 students at SMA Negeri 1 Mantup, with 30 students in each class. Each class was divided into five groups, with the number of each group of 6 students. The data used in this study came from instruments in the form of a questionnaire that assessed students' learning styles in the experimental class and a post-test that measured mathematical critical thinking skills. The posttest consists of three essay questions covering 4 critical thinking indicators: interpreting, analyzing, evaluating, and inferring. The scores obtained by students will be assessed using the T-test or independent samples T-test. Based on the research findings, three learning style groups were obtained with 14 students of visual learning style, eight of auditorial learning style, and eight of kinesthetic learning style, respectively. The post-test results of each class showed that there were differences in mathematical critical thinking skills between students who received differentiated learning and students who received undifferentiated learning with a t value of 2.781 exceeding the t table value of 2.001 which means there is an influence between differentiated learning on mathematical critical thinking skills.

Keywords: mathematical critical thinking, differentiated learning

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INTRODUCTION

Indonesia has undergone major changes to its education system at the implementation stage due to the impact of COVID-19, which has resulted in sectors of life undergoing changes that also require rapid adjustment, including education. For two years, students have been doing online learning to prevent the spread of the coronavirus. But the reality is that online learning does not place effective and meaningful learning for students. There are many obstacles that students face, the only mistake being the difficulty of concentrating on studying at home. Therefore, the government reviewed and issued guidelines that could form an adaptive curriculum during the current pandemic. The Minister of Education and Culture's Nadiem Makarim said that the Independent Curriculum is a further development through Curriculum 13 which is expected to produce new learning (Jojo & Sihotang, 2022). While according to (Rafiska & Susanti, 2023), the application of freedom of learning brings up the concept of freedom of learning for students. The students are given the freedom to be creative, independent, and also to innovate in the implementation of learning.

Learner-centered learning to meet their needs according to the objectives of the independent curriculum, namely implementing differentiated learning. Differentiated learning

is a learning project that takes into account the needs of students in terms of their learning abilities, learning profiles, interests & talents (Tomlinson, 2001). Differentiated learning is an educational approach that aims to meet the diverse needs and characteristics of each student. According to (Andini et al., 2000), differentiated learning can take a number of approaches to product, process and content. This research will focus more on the process approach. Example of suitable learning for students to receive facts or ways of learning is by using differentiated learning using the process approach.

(Tomlinson, 2001), said that there are three aspects that categorize students' learning needs. The three aspects include: (1) Learning readiness is the ability to research new material; (2) Interest is one of the crucial motivators for students to actively participate in the stages of teaching and learning activities; and (3) Learning profile is a student's preferred approach to learning, which is determined by environment, background, learning style, etc. Learners' habits during learning affect their learning style. The learning style is a combination of learning activities that process information and retain facts to make the learning process more meaningful.

According to (Alhafiz, 2022), each person has a different tendency to accept knowledge or learning. By using differentiated learning, teachers can meet all the differences in students, one of which is in terms of their learning style. While according to (Jannah et al., 2022), The learning style is an approach that describes how individuals learn as well as how each person focuses on the process of dealing with difficult and new knowledge from a variety of perspectives. Three styles of learning are abbreviated as VAK (Visual, Auditory, Kinesthetic). Visual learning styles tend to be able to process information using visual media to help them process information. Compared to visual learning style students, students with auditory learning style tendencies process information using listening, for example listening to lectures, presentations, or using media in the form of recordings to help them learn. The last learning style is kinesthetic. Kinesthetic learning styles, tend to receive or learn information more easily when practicing certain exercises using the five senses (Alhafiz, 2022).

Learning in the 21st century is learning that combines literacy, information literacy, skills and attitudes, and technology management. As time goes by and times change, the globalization era has had a wide influence on all levels of society around the world, including education. Among the real challenges is that education must be able to produce human resources and all skills or what we call 21st century competencies. Based on the statement (Setyautami, 2020) that "some of the skills that must be possessed in 21st century competencies such as skills in problem solving, critical thinking, collaboration and communication". Underpinning the goals of 21st century education is how one thinks about issues or problems and how they can be solved (Tresnawati et al., 2017). It shows that one of the 21st century skills that today's students must have is critical thinking. So, the researcher focuses more on critical thinking competence.

According to (Abdullah, 2016), Critical thinking is a process that has a purpose to enable us to build decisions logically, as a result being able to do what we think is best about the truth. Currently, students are required to have reasoning in critical thinking, especially in mathematics. Mathematical critical thinking is the ability to use prior knowledge, mathematical reasoning, as well as using cognitive strategies to generalize, prove, and evaluate mathematical situations in general. The indicators of critical thinking based on the statement (Facione, 2020), "There are 6 aspects, namely : interpretation, analysis, evaluation, inference, explanation and self-regulation".

According to the results of observations at the Senior High School (SMA) Negeri 1 Mantup, it was found that the ability of students to think as well as make decisions was very lacking, seen from the learning activities in the classroom when in groups, students tend to be silent and when decision making is only done by a few students, while others are just silent. In line with the opinion (Wibowo et al., 2022), students' lack of critical thinking skills is caused by their tendency to be passive learners, finding learning activities boring and relying only on

note-taking and memorization. Therefore, students must be encouraged to ask questions related to the material being taught. Sometimes, this makes it difficult for them to think critically and tend to be passive during learning activities in the classroom.

Effective education can develop students' ability to think critically. An example of factors that influence students' lack of critical thinking is that learning is not effective enough to develop students' potential, talents and interests. Sometimes this makes it difficult for them to think critically and tend to be passive during learning activities in the classroom. Basically, students should be active when learning. However, a number of studies show that students only receive information through teachers, teachers only provide information in learning activities without involving students in mathematical critical thinking. Students' critical thinking skills have not been well trained (Sunaryo, 2014).

The author's research examines how differentiated learning affects mathematical critical thinking. The researcher used four indicators (Karim & Normaya, 2015) in this study. These indicators assume that Facione is measuring critical thinking because of their relevance to the research topic. Here are the critical thinking indicators: (1) Interpret; (2) Analyze; (3) Evaluating; (4) Inferring.

METHOD

By using an experimental group and a control group, this study utilized a quasi-experimental approach. Although there were variations in the implementation, both groups were asked to complete a posttest that measured critical thinking indicators. The following is an illustration of the research design used the nonequivalent posttest-only control group.

Table 1. The Nonequivalent Posttest-Only Control Group

Group	Treatment	Post-Test
Experiment	X_1	O_1
control	X_2	O_2

This study used random sampling. Sampling involves randomly selecting individuals from the sample population without regard to stratification. Thirty students each from Class X-1 and Class X-3 were selected for the study. In this study, Class X-1 was designated as the differentiated learning experimental group. (1) Giving students a questionnaire to determine their visual, auditory, and kinesthetic learning styles. (2) Carry out critical thinking tests on experimental students and control students. Post-test of this research uses arithmetic sequence material and three essay test questions that have passed the expert validation stage and have been tested in classes other than the subject of this research to see if the post-test can be implemented as a test of students' mathematical critical thinking skills and has been tested for validity and reliability.

Table 2. Mathematical Critical Thinking Ability Test Questions

No.	Questions
1.	Today Ani wants to watch a horror movie in the theater. In the movie theater studio there are several rows of seats with numbers 1-120 seats. If the first row has 12 seats, the second row has 18 seats, the third row has 24 seats, and so on until the 120th seat. It turns out that Ani gets a seat at number 96, so help Ani to find her seat in which row?
2.	A company will hold a work meeting, where for the meeting each sitting position is facing each other. The company only has 1 rectangular table with 3 chairs, because the table owned by the company is not long enough. Then the table must be combined so that it becomes 6 chairs.

No.	Questions
	What is the formula to determine the number of tables that must be combined if there are 132 employees participating in the meeting?
3.	The library at SMA Negeri 1 Mantup wanted to organize the bookshelves. While arranging, the officer must write down the number of books on each shelf so that they are not lost. The librarian started counting from the first shelf with 7 stacks of books, right on the next shelf there were 10 stacks of books. When doing the calculation, it turns out that there are shelves that have not been counted. So help the librarian to find out on which shelf, there are 100 stacks of books?

In Table 2, a validity test was conducted in class X-2 with 32 students to determine the validity of the items of the test sheet whether they were valid. This research used SPSS to compare r count with r table count at 5% significance. If r count exceeds r table then the question is valid and the results are as follows.

Table 3. Validity Test Results

Questions	r count	r table	Description
1	0,896	0,349	Valid
2	0,932	0,349	Valid
3	0,901	0,349	Valid

The validity of the three questions in Table 2 is as in Table 3. This allows the research variables to proceed to the reliability testing stage of the testing process. Because this research instrument is in the form of an essay, the researcher uses Cronbach's alpha to determine its reliability. When the alpha value is greater than 0.60, the reliability measurement using Cronbach's Alpha test is considered reliable (Syamsuryadin & Wahyuniati, 2017). Reliability evaluation results are as follows.

Table 4. Reliability Test Results

Variable	r Alpha	Rules	Interpretation
Mathematical critical thinking ability test results	0,796	0,60	Reliable

The reliability value of the mathematical critical thinking ability test questions is greater than 0.60 and less than 0.80 indicating high reliability, according to the results of the reliability test of the test questions using SPSS.

The researcher used radar plots with markers and parametric statistics to test the hypothesis based on the average of the class posttest results. To test the hypothesis, this study compared group means using the t-test, namely the independent sample t-test. By testing the average difference in posttest results between classes, the following hypothesis formulation.

$H_0 : \mu_1 \leq \mu_2$ There is no significant difference in mathematical critical thinking ability between students who apply differentiated learning and students who apply undifferentiated learning.

$H_1 : \mu_1 > \mu_2$ There is a significant difference in mathematical critical thinking skills between students who apply differentiated learning and students who apply undifferentiated learning.

Based on the test, the following conclusions can be drawn (1) If t count $>$ t table, then H_0 is rejected and H_1 is accepted; and (2) If t count $<$ t table, then H_0 is accepted and H_1 is rejected.

RESULTS AND DISCUSSION

The results of the research in the experimental class to determine the learning style of students were obtained through a learning style questionnaire using three aspects: visual, auditory and kinesthetic (VAK) which was adopted from (Sugianto, 2021).

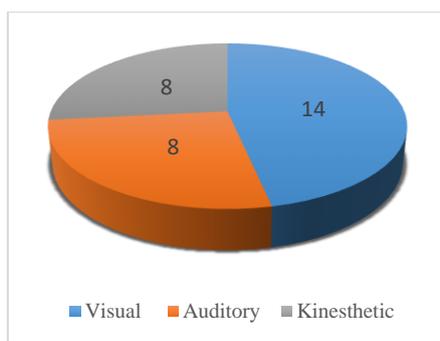


Figure 1. Result of Student Learning Style Questionnaire

Figure 1 displays the results of the learning style questionnaire, which shows that fourteen students learn best through sight, eight through sound and eight through movement. Based on these results, the majority of students fall into the visual learning style category. Most of the students fall into visual learners, as stated in the research (Ishartono et al., 2021).

Table 5 displays the researcher's learning activities related to the Problem Based Learning (PBL) model in Class X-3 (control class) and Class X-1 (experimental class).

Table 5. Research Activities in Learning

Experiment Class PBL with Differentiated Learning	Control Class PBL with Non Differentiated Learning
Stage 1. Orienting learners to the problem	
<ul style="list-style-type: none"> - The teacher explains the learning objectives. - The teacher shows a video related to arithmetic sequence as a trigger and asks questions related to the problems in the video. 	<ul style="list-style-type: none"> - The teacher explains the learning objectives. - The teacher explains the material related to Arithmetic Rows and gives questions containing contextual problems related to Arithmetic Rows.
Stage 2. Organizing learners	
<ul style="list-style-type: none"> - The teacher divides learners into 5 groups (consisting of 6 people per group) based on learning styles, namely: <ul style="list-style-type: none"> ➤ Learners with visual learning styles are given assistive media in the form of LKPD and reading materials. ➤ Learners with auditory learning styles are given LKPD facilities and learning videos. 	<ul style="list-style-type: none"> - The teacher divides the learners into 5 groups (consisting of 6 people per group) based on the lottery. - The teacher provides LKPD containing contextual problems related to Arithmetic Rows. - Learners critically identify the contextual problem and follow the steps on the LKPD.

Experiment Class PBL with Differentiated Learning	Control Class PBL with Non Differentiated Learning
<ul style="list-style-type: none"> ➤ with kinesthetic learning styles are given LKPD and media. - The teacher provides LKPD containing contextual problems related to Arithmetic Rows. - Learners critically identify the contextual problem and follow the steps on the LKPD that have been adapted to the learning style. 	
Stage 3. Guiding individual and group investigations	
<ul style="list-style-type: none"> - The teacher guides learners to be actively involved in their group discussions. 	<ul style="list-style-type: none"> - The teacher guides learners to be actively involved in their group discussions.
Stage 4. Develop and present results	
<ul style="list-style-type: none"> - Compile the results of the problem-solving discussion. - The teacher asks each group to present the results of their discussion in writing and orally in turn. 	<ul style="list-style-type: none"> - Compile the results of the problem-solving discussion. - The teacher asks each group to present the results of their discussion in writing and orally in turn.
Stage 5. Analyze and evaluate the solution process and results	
<ul style="list-style-type: none"> - The teacher guides the class discussion by providing direction and reinforcement. 	<ul style="list-style-type: none"> - The teacher guides the class discussion by providing direction and reinforcement.

After two learning activities, researchers gave a post-test on arithmetic sequence material to assess students' mathematical critical thinking skills.

Experiment class used in this research is Class X-1. Here are the results of the analysis of the various mathematical learning styles of class X-1 students and their critical thinking skills.

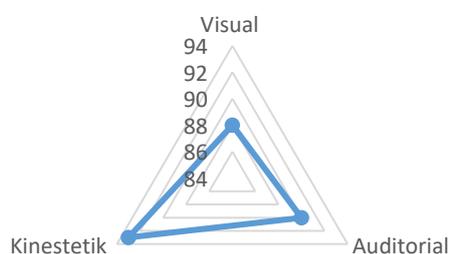


Figure 2. Results of Mathematical Critical Thinking Ability Based on Learning Style

From the results of the posttest in Figure 2, the highest average value is obtained by the group with a kinesthetic learning style of 93, while the auditorial group gets an average of 90, and the visual group gets an average of 88. According to (Safitri & Miatun, 2021), in his research said that the average test results of the critical thinking skills of the kinesthetic group were quite good while for the auditorial and visual learning styles the average test results were

good. From the results of this study, it turns out that there are differences with the results of the research listed in Figure 2. Other variables may contribute to differences that are ignored by researchers. Then these factors can be used as further research.

It is more than just averaging the performance of the experimental classes according to their preferred learning method. The following is a comparison of the experimental class (X-1) and control class (X-3) on mathematical critical thinking skills.

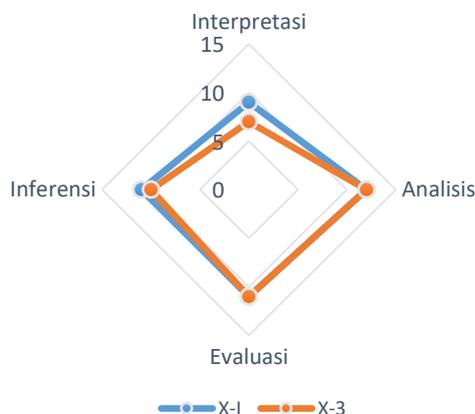


Figure 3. Mean Indicator of Mathematical Critical Thinking Ability

Class X-1 (experimental group) had an average score of 9 on the interpretation index, 12 on analysis, 11 on evaluation, and 11 on reasoning, according to this radar. For indicators, the class average score was 7, for analysis was 12, for evaluation was 11, and for reasoning was 10. From the looks of it, both groups successfully completed the mathematical critical thinking ability test and scored 12 on the mathematical critical thinking ability test. In line with (Avandra & Desyandri, 2023), in his research explained that the highest average value of critical thinking tests was in the analysis indicator, as well as other indicators. Differentiated learning that improves mathematical critical thinking is presented below:

Table 6. Descriptive Statistics of Critical Thinking Ability Test Results

Class	N	Min	Max	Mean
X-1	30	73	100	89.80
X-3	30	65	98	83.63

The results showed that the experimental group X-1 had an average post-test score of 89.80 and the control group X-3 had an average post-test score of 83.63. Based on these findings, the experimental group using differentiated learning has a higher average than the control group.

Normality Test

Normality test aims to determine whether data is normally distributed. To conduct the Kolmogorov Smirnov test at a significance level of 5% (or 0.05), this study used SPSS software.

Table 7. Normality Test Results

Kolmogorov-Smirnov ^a				
	X	Statistic	df	Sig.
Posttest	1	.148	30	.091
	3	.149	30	.088

The posttest results of both the control and experimental groups are in the normal range as shown in the previous table and X-I as the experimental group has a significance level of 0.091 > 0.05.

Homogeneity Test

Knowing whether the research samples have the same variance is the essence of the homogeneity test. This study used SPSS to run the homogeneity test. The following are the findings of the test.

Table 8. Homogeneity Test Results

		Levene Statistic	df1	df2	Sig.
Posttest	Based on Mean	.027	1	58	.870

The t-table value is: $0,870 > 0,05$. Thus the variance of the experimental and control class posttest data is homogeneous, meaning it has the same meaning. The next t-test or hypothesis test is carried out after checking homogeneity and normality.

Independent Sample T-Test

Independent samples to determine the significance of differences in group means. This test can reject or accept the hypothesis. Check and answer whether differentiated learning affects high school students' mathematical critical thinking by using SPSS.

Table 9. Hypothesis Test Results Independent Sample T Test

		F	Sig.	t	df	Sig. (2-tailed)
Posttest	Equal variances assumed	.027	.870	2.781	58	.007
	Equal variances not assumed			2.781	57.863	.007

In Table 9. the data obtained is homogeneous. To determine the results of hypothesis testing in this study using the upper table or Equal variances assumed of 2.781. Based on the t distribution percentage point table with df 58, the t table is 2.001. Then the value of t count $>$ t table is $2.781 > 2.001$. So it can be concluded that H_1 is accepted, which means that the mathematical critical thinking skills of students who apply differentiated learning are better than students who apply non-differentiated learning. So there is an influence between differentiated learning on mathematical critical thinking skills.

This study shows how mathematical critical thinking skills are affected by differentiated learning. This is in line with research (Avandra & Desyandri, 2023) Differentiated learning shows that well-designed learning can have an impact on students' critical thinking skills. According to research (Nasrulloh et al., 2023) Students' critical thinking skills can be greatly improved through the implementation of differentiated learning.

CONCLUSION

Based on the findings presented earlier, the experimental class (X-1) became the main focus of the differentiated learning strategy used in this study. The best level of mathematical critical thinking was obtained in the kinesthetic learning style. While for the average class using differentiated learning or experimental class is 89.80 and the average class that does not use differentiated learning or control class is 83.63. Furthermore, the results obtained t count $>$ t table of $2.781 > 2.001$ indicate that differentiated students are better than undifferentiated students in mathematical critical thinking. As a result, mathematical critical thinking ability is influenced by differentiated learning.

RECOMMENDATION

This research needs to explore other learning methods and differentiated learning methods to assess students' mathematical critical thinking. Educators should also focus on learning methods and strategies to engage and impress students.

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