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# The Effect of Differentiated Instruction based on Multiple Intelligences toward Critical Thinking and Student Self-Efficacy

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***Abstract.*** *Mathematics learning is often teacher-centered, where teachers directly present material to students without considering students' learning needs and improving their critical thinking skills. The lack of students' self-efficacy as a motivational factor will affect the development of their critical thinking level. This study aims to determine the effectiveness of differentiated instruction based on multiple intelligences to improve student's critical thinking and self-efficacy. This research employed a quantitative approach and a quasi-experimental research design. This study focused on mathematics learning using the differentiated instruction approach in the vector topic for Year 10 students in one senior high school at Langsa, Aceh, Indonesia and compared differentiated instruction and scientific approach. Based on the population, the experimental group implemented differentiated instruction, and the control group applied a scientific approach. The hypothesis was tested using MANOVA, Hotelling's $T^2$ test, and independent sample t-test. The effect size of differentiated instruction was determined based on the Cohen d-effect size calculation. The results of this study indicate that differentiated instruction has a moderate effect on students' critical thinking but does not significantly affect their self-efficacy. Therefore, differentiated instruction can be considered as one of the effective approaches for enhancing students' critical thinking skills.*

***Keywords****: critical thinking, differentiated instruction, multiple intelligences, self-efficacy*

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## Introduction

The formal education system involves students with a variety of differences. Achieving the educational goals outlined in law no. 19 of 2005 requires efforts to ensure effective and efficient learning and to accomplish the desired learning objectives, even though it may require dealing with students' characteristics. Individual has distinct characteristics and strengths in learning, with intelligence being one of the key differences among students. Intelligence plays a crucial role in influencing the success of a student's learning process. It is essential to implement a multiple intelligences framework to ensure that schools meet the individual needs of each student based on their unique strengths (Maharani et al., 2020; Winarti et al., 2019). Multiple intelligences are commonly applied in early childhood education, which are less frequently utilized in elementary, middle, and high school settings, which still tend to rely on traditional, authoritarian teaching methods (Ernawati et al., 2017). Many educators believe recognizing and addressing multiple intelligences will significantly enhance students' learning outcomes (Xu, 2020).

Mathematics education in the current global era must align with 21st-century skills, including learning and innovation skills, which include critical thinking and problem-solving, communication and collaboration, creativity, and innovation (Nurkhin & Pramusinto, 2020). Critical thinking is the ability to identify problems, analyze potential solutions (Moeti et al., 2017), evaluate gathered from, or generated by, observation, experience, reflection, reasoning, or communication (Kumar, 2017), and analyze and evaluate thinking to improve it (Paul & Elder, 2019), think by the rules of logic and apply it to real-life problems (Karakoç, 2016), the truth of an opinion or argument, draw logical, well-supported conclusions (Elder & Paul, 2020). Therefore, if students have critical thinking skills, they can think according to the rules of logic and probability and apply them to real-life problems (Karakoç, 2016).

Students often struggle to understand vector problems and accurately sketch solutions, particularly when visualizing unit vector notation (Barniol & Zavala, 2014). Traditionally, classrooms have been teacher-centered, with the teacher directly presenting the material to students, which limits student participation and the development of critical thinking skills (Agus, 2019). For example, in the vector addition topic, students depict vectors A and B at one point without understanding the reason behind it. They may incorrectly assume that vectors on a Cartesian diagram cannot be moved and the triangle rule cannot be applied, leading to a lack of understanding in analyzing mathematical calculations (Jewaru et al., 2021). This reflects a deficiency in critical thinking skills, as students struggle to identify problems and provide appropriate explanations during problem-solving processes (Slamet et al., 2020).

Self-efficacy is the belief that students have in their abilities to complete tasks (Bandura, 2015; Maddux, 2016), their confidence in their skills (Schunk & DiBenedetto, 2016), their belief in situations and produce positive outcomes (Schunk, 2023), achieving positive outcomes from specific actions (Gangloff & Mazilescu, 2017), and their ability to make decisions in various situations (Bartimote-Aufflick et al., 2016). When students lack efficacy in their abilities to learn and complete mathematical tasks, they are often hesitant to present their work in front of others, fearing making mistakes; they struggle with more complex materials, lack the confidence to ask questions, and are reluctant to express their opinions (Agus, 2019). The relationship demonstrated that higher academic self-efficacy is associated with better critical thinking skills, with self-efficacy being one of the strongest predictors of critical thinking (Vachova et al., 2023). Therefore, mathematics self-efficacy is confidence in one's capacity to carry out or complete a mathematical task (Bhowmick et al., 2017).

Previous research has shown a significant positive correlation between student self-efficacy and critical thinking (Dehghani et al., 2011), there is a significant relationship between self-efficacy and student mathematics learning outcomes in Indonesia (Muhtadi et al., 2022), students'

critical thinking abilities (Turan-Oluk et al., 2022) and students' academic achievements (Turner et al., 2009). When students' learning demands are successfully met, their self-efficacy increases (Zhen et al., 2020). Teachers can use differentiated instruction to enhance students' academic performance (Toledo, 2023). Differentiated instruction based on multiple intelligences effectively enhances mastery of scientific concepts, particularly in remembering, understanding, and applying (Anggoro et al., 2024). There is a significant relationship between self-efficacy, self-regulation, self-confidence, task difficulty, and multiple intelligences (Hernández-Barco et al., 2021).

Learning in the 2013 curriculum uses a scientific approach with five steps: observing, asking, trying, associating, and communicating (Permendikbud, 2014). Applying a scientific approach in learning aims to accustom students to thinking, behaving, and working using scientific principles and steps (Musfiqon & Nurdyansyah, 2015). The scientific approach is often compared to other learning approaches and strategies, such as problem-solving strategies, which are more effective than the scientific approach (Tambunan, 2019) and increased adaptive reasoning of students in geometry learning with a scientific approach (Andika et al., 2020). The findings in the two studies show different things. Therefore, it cannot be stated clearly that the scientific approach is better than another learning approach. It is necessary to compare the scientific approach with new learning approaches promoted in curriculum development to improve the quality of learning in Indonesia.

Currently, the learning approach commonly used in this school is the scientific approach. The *Pendidikan Guru Penggerak* (Mobilizing Teacher Education) program in Indonesia focuses on student learning needs through differentiated instruction. This program highlights various aspects of student needs and the achievement of learning objectives (Permendikbudristek, 2022). Ideally, adjusting the components of this educational program would lead to changes in educational plans tailored to students' profiles and characteristics (Caputi & Garrido, 2015).

Differentiated instruction is proposed to enhance students' critical thinking skills and self-efficacy in mathematics. The primary research questions are: 1) Does the differentiated instruction approach influence increased critical mathematical thinking and student self-efficacy in learning mathematics? 2) Is the differentiated instruction approach more effective than the scientific approach in enhancing students' critical thinking in mathematics? and 3) Is differentiated instruction more effective than a scientific approach regarding student self-efficacy?

## Method

This study used a quantitative approach with a quasi-experimental design type. Experimental research is a method that allows for testing hypotheses regarding causality (cause

and effect), manipulating independent variables, and exploring cause-and-effect relationships (Johnson, 2014). The study included two independent variables: the learning approaches (differentiated instruction and scientific approach) and two dependent variables, critical thinking skills and self-efficacy. The study design used was a pretest-posttest control group, which required experimental and control groups.

The study's population consists of all tenth-grade high school students. Experimental and control classes are determined through cluster random sampling. Cluster random sampling involves selecting groups, or clusters, as sampling units instead of individual elements, with these clusters being randomly chosen (Johnson, 2014). In the clustering sampling procedure, researchers first determine the class and then identify the names of individuals in that class (Creswell & Creswell, 2014). Furthermore, sampling was conducted on these individuals. The high schools in Langsa City have 10 classes of grade X. The experimental class uses differentiated instruction and one control class uses a scientific approach. The learning intervention occurred across 6 meetings with the vector topic based on basic competencies 3.2 and 4.2 in the grade X mathematics curriculum.

Indicators of critical thinking are (1) Interpretation: categorization, decoding significance, clarifying meaning; (2) Analysis: examining ideas, identifying and analyzing arguments; (3) Evaluation: assessing claims and arguments; (4) Inference: querying evidence, conjecturing alternatives, drawing conclusions; (5) Explanation: stating results, justifying procedures, presenting arguments; and (6) Self-regulation: self-examination, self-correction (Ernst & Monroe, 2006). There are three critical thinking competencies: assuming, triggering arguments, and drawing conclusions (Boa et al., 2018). The collected references are then synthesized into four indicators of critical thinking used in the research: determining the main issues, analyzing the precision of problem-solving procedures, evaluating the accuracy of solving issues arguments, and providing rational justifications for the conclusions drawn from the provided solutions.

Measurement of student self-efficacy is divided into three dimensions, namely: (1) Level, the difficulty of the tasks that students do; (2) Strength, the amount of effort made by students which influences the level of resilience and tenacity in completing various tasks, (3) Generality; students' confidence in completing various tasks (Bandura, 2015), Self-efficacy refers to the belief that one can master a situation or concept and achieve desired outcomes (Nichols, 2010). Student self-efficacy in mathematics is the student's self-confidence in their ability to solve problems and complete tasks without comparing them with the abilities of others so that they can achieve success in learning mathematics accompanied by a sense of confidence in the efforts made, the choices that have been made, and having perseverance (Novferma, 2016). The

collected references are then synthesized into five indicators of self-efficacy used in the research. Self-efficacy is confidence in completing tasks in mathematics with varying levels of difficulty, confidence in solving various types of mathematical problems, confidence in facing diverse situations and conditions, confidence that success will be achieved, and confidence in persevering in solving mathematical problems.

The instruments for critical thinking and self-efficacy questionnaire were developed by researchers and reviewed by two expert lecturers in mathematics learning and assessment, namely DUW and HT. The data collection methods are (1) Tests consisting of multiple-choice questions administered to 10th-grade students. The same questions are given in both the pretest pretest and posttest, focusing on vector material and critical thinking indicators. The critical thinking ability test consists of four questions, with a maximum score of 20. (2) Questionnaires, which are non-test instruments, include a self-efficacy questionnaire and learning observation sheets. The self-efficacy questionnaire is split into pretest and posttest sections, using a Likert scale with 5 response options: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. The student self-efficacy questionnaire includes 25 items: 20 positive statements and 5 negative statements.

The following is an example of a question from a critical thinking indicator coded with CT (Critical Thinking). The test items involve CT4, which requires students to explain conclusions based on logical reasoning. For example, the test question asks: "Faruq and his younger brother were playing on a field, dribbling the ball. Faruq ran east for 4 meters, then turned north for 3 meters. After resting, he walked west for 8 meters. His younger brother ran west for 5 meters, then south for 2 meters, and east for 10 meters. Determine the difference in their total distances traveled and explain your reasoning.

The differentiated instruction approach tailored problems to meet students' individual needs. The student worksheet design was based on the results of students' MIT tests, forming three study groups based on musical, interpersonal, and naturalist intelligence. Table 1 is one of the student activities on the material on the definition of vectors in a plane.

Table 1. Student activities in three groups

| Group | Description | Activity |
|---|---|---|
| Musical | Students with musical intelligence while listening to the music with headsets will not disturbed by other groups while working on the student worksheet. | Look at the map below.<br>One day, three students, Angga, Budi, and Candra, wanted to watch an art performance that would be held at the Langsa Football Stadium. They went riding their motorbikes from different places. Angga left from Public Senior High School 1 Langsa, Budi left from Warkop bg Nawi and Candra left from the Baitul Huda Mosque. |

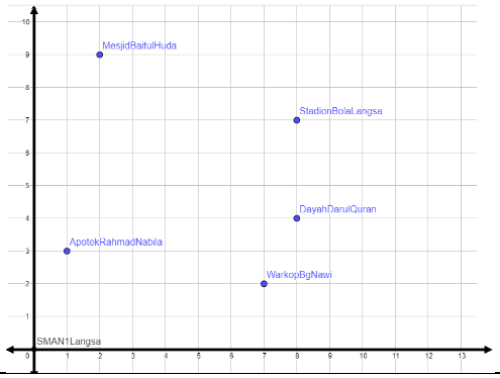
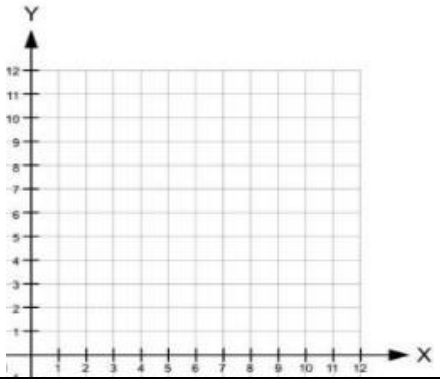
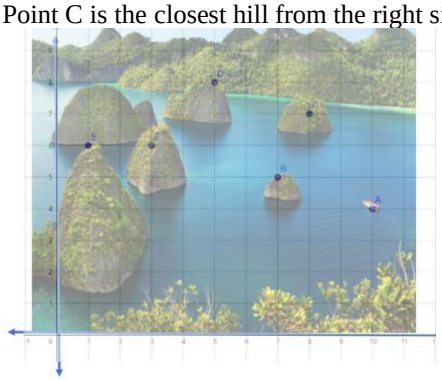
| Group | Description | Activity |
|---|---|---|
| | |  |
| Interpersonal | - Students identify problems in position vectors on checkered paper.<br>- Students play with checkered paper and small balls twisted from paper.<br>- Students present vector problems based on the course of the game in groups.<br>- Students observe a vector line and discuss it with friends in groups. | Use the following checkered paper to play a game with your friends. Make a super small ball from twisted paper. Place the ball on the checkered paper. The game rules are that the first player places the ball anywhere on the checkered paper and marks it. The next player blows on the ball to move it to another place. The last position of the ball is also marked. Repeat moving the ball until all group members have had an equal turn.<br>  |
| Naturalist | Students with naturalist intelligence observe the definition of vectors with pictures of nature and observations of objects/living things outside the classroom. | Look at the picture below.<br>If the horizontal and vertical lines represent the x and y axes as in Cartesian coordinates. In the picture,<br>mark three points (A, B, and C) with the provisions.<br>Point A is the boat.<br>Point B is the closest hill from the left side of the boat.<br>Point C is the closest hill from the right side of the boat.<br>  |

Table 1 provides an overview of how students work on vector problems based on their respective intelligence. Construct validity testing follows content validity testing and factor analysis. Before conducting the factor analysis, the correlation between variables is checked

using the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy. Reliability refers to the consistency or stability of measurement results. Reliability testing was conducted using IBM SPSS Statistics Version 26, with a Cronbach's Alpha value of 0.55 for the knowledge test.

Data analysis was conducted using both descriptive and inferential techniques. Descriptive analysis included the number of students, maximum and minimum scores, average scores, variance, and standard deviation for the pretest, posttest, and questionnaire results from the experimental and control groups. The categorization of pretest, posttest, and student questionnaire scores followed specific criteria and interval guidelines (Azwar, 2012). Categories of critical thinking and self-efficacy can be seen in Table 2.

Table 2. Critical thinking and self-efficacy value categories

| Critical Thinking | Self Efficacy | Categories |
|---|---|---|
| $x \geq 14{,}99$ | $x \geq 67{,}5$ | Very high |
| $11{,}66 \leq x < 14{,}99$ | $52{,}5 \leq x < 67{,}5$ | High |
| $8{,}33 \leq x < 11{,}66$ | $37{,}5 \leq x < 52{,}5$ | Medium |
| $5 \leq x < 8{,}33$ | $22{,}5 \leq x < 37{,}5$ | Low |
| $x < 5$ | $x < 22{,}5$ | Very Low |

The categories of levels of critical thinking and self-efficacy in Table 2 can make it easier for researchers to group students based on their ability level. Based on the research problem, one hypothesis will be tested using Multivariate Analysis of Variance (MANOVA) and Hotelling's $T^2$ test, while the other hypothesis will be examined through independent sample t-tests. The impact of the dependent variables (critical thinking and self-efficacy) on the independent variable (teaching approach) will be evaluated using Cohen's d to determine effect size. The hypotheses used to answer the research questions are: (1) The differentiated instruction approach has an effect on increasing students' critical mathematical thinking and self-efficacy in vector material in mathematics learning, (2) The differentiated instruction approach is more effective than the scientific approach in terms of the average students' critical mathematical thinking, and (3) The differentiated instruction approach is more effective than the scientific approach in terms of the average students' self-efficacy.

## Results and Discussions

The critical thinking test scores for students in the experimental and control groups are provided in the attachment. According to the data, the average pretest score for critical thinking skills in the experimental group is lower than in the control group, 0.8 in the experimental group versus 1 in the control group. Additionally, the variance in the control group is greater than in the experimental group in Table 3.

The control class showed a greater variance in pretest scores, with higher average posttest critical thinking percentages than the experimental class, as shown in Table 3. However, the

differentiated instruction group achieved higher mean posttest scores (8.63, 43.14%) than the scientific approach group (6.86, 35.57%), indicating improved critical thinking in the experimental class. Hypothesis testing steps included assessing multivariate normality using Mahalanobis Distance and Chi-Square tests.

$$d_j^2 = (x_j - \bar{x})' S^{-1} (x_j - \bar{x}), \quad j = 1,2,\dots,n$$

Table 3. Calculation of student posttest data per critical thinking indicator

| | **Experimental Classes** | | | | **Control Classes** | | | |
|---|---|---|---|---|---|---|---|---|
| | Average *PretestPretest* | | Average *Posttest* | | Average *PretestPretest* | | Average *Posttest* | |
| | $\bar{X}$ | % | $\bar{X}$ | % | $\bar{X}$ | % | $\bar{X}$ | % |
| CT1 | 0,23 | 5,71 | 1,23 | 30,7 | 0,37 | 9,29 | 1,31 | 32,86 |
| CT2 | 0,06 | 1,43 | 1,83 | 45,7 | 0,17 | 4,29 | 1,86 | 46,43 |
| CT3 | 0,31 | 5,24 | 2,94 | 49 | 0,29 | 4,76 | 1,8 | 30 |
| CT4 | 0,2 | 3,33 | 2,63 | 43,8 | 0,2 | 3,33 | 1,94 | 32,38 |
| Total | 0,8 | 4 | 8,63 | 43,14 | 1,03 | 5,14 | 6,91 | 34,57 |

The assumption of multivariate normality is fulfilled if the p-value is obtained by 50% of the Mahalanobis Distance value is less than or equal to. In addition, you can also use other methods by creating $X_p^2$ (0,50) scatter plots from $d_j^2$ and $q_i$. The normality plot of scatter-plot data from Mahalanobis Distance and Chi-Squares in the experimental and control classes are shown in Figure 1.

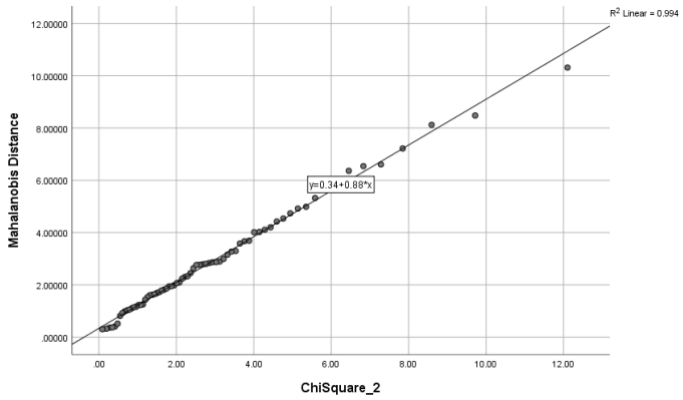



Figure 1. Scatter plots of correlation analysis between mahalanobis distance and chi-square

The correlation coefficient is between -1< r <1; if the correlation coefficient > r table or sig value <0.05, then there is a significant correlation (Johnson & Wichern, 2007). Figure 1 shows the Pearson correlation test results on Mahalanobis Distance and Chi-Square; the value is 0.997 with a significance of 0.000, indicating that the data after treatment in the experimental and control classes are normally distributed. The Mahalanobis distance is widely used in multivariate statistics and differs from the Euclidean distance in that it accounts for correlations between variables (Ghorbani, 2019).

A homogeneity test was conducted to check for the equality of covariance matrices using Box's M test and for variance, homogeneity using Levene's Test, both at a significance level of 0.05. The Box's M test results on the posttest scores and final questionnaire indicate that the p> 0.05. This result indicates that both classes have homogeneous covariance matrices, thus meeting the assumption of homogeneity and hypothesis testing using MANOVA. The research hypothesis test with the Multivariate Tests test statistics observed is the Hotelling's value ($T^2$) listed in the Hotelling's trace. The test uses the following formula: $F_{hitung} > F_{(\alpha,p,n_1+n_2-p-1)}$ (Stevens, 2009).

- $F = \frac{(n_1+n_2-p-1)}{(n_1+n_2-2)p} T^2$ With $T^2 = \left(\frac{n_1 n_2}{n_1+n_2}\right)(\bar{x}_1 - \bar{x}_2)'(S)^{-1}(\bar{x}_1 - \bar{x}_2)$

In Hotelling's test ($T^2$), the null hypothesis is rejected if the p-value < 0.05. Table 4 shows the results of the statistical calculations with the application.

Table 4. Results of multivariate tests

| **Multivariate Tests** | | | | | | |
|---|---|---|---|---|---|---|
| | Value | F | Hypothesis df | Error df | Sig. | Partial Eta Squared |
| Pillai's trace | .136 | 3.507a | 3.000 | 67.000 | .020 | .136 |
| Wilks' lambda | .864 | 3.507a | 3.000 | 67.000 | .020 | .136 |
| Hotelling's trace | .157 | 3.507a | 3.000 | 67.000 | .020 | .136 |
| Roy's largest root | .157 | 3.507a | 3.000 | 67.000 | .020 | .136 |

Table 4 shows that F < 0.05, the null hypothesis ($H_0$) is rejected, indicating significant mean differences between the differentiated instruction and scientific approach classes. Post-hoc independent t-tests confirm that differentiated instruction enhances mathematical critical thinking but does not significantly affect self-efficacy. Similar analyses were conducted to compare pretest and posttest scores, identifying variables contributing to the observed differences, as seen in Table 5.

Table 5. Results of the independent sample T-test

| | **t-test for the quality of means** | |
|---|---|---|
| | T | Sig (2-tailed) |
| Critical Thinking | 2,266 | 0,027 |
| Self-Efficacy | 1,785 | 0,079 |

Table 5 explains that the differentiated instruction approach was less effective than the scientific approach in improving self-efficacy, with a significance level of $p$ >0.05, indicating no significant difference between the two groups. Cohen's d was calculated to evaluate the effect size for each dependent variable, as seen in Table 6.

Based on Table 6, the calculation of Cohen's d-value obtained from the average posttest score and standard deviation of critical thinking shows moderate effect of the differentiated instruction approach on students' critical thinking. As indicated by the value of 0.54, the effect

of the differentiated instruction approach on students' critical thinking falls into the moderate category.

Table 6. Cohen's D values for critical thinking

| Class | Mean Posttest Score | Standard Deviation | Cohen's d Value | Category |
|---|---|---|---|---|
| Experimental | 8,63 | 3,309 | 0,54 | Moderate |
| Control | 6,86 | 3,261 | | |

*Implementation of Differentiated Instruction (DI)*

Differentiated instruction, introduced by Carol Ann Tomlinson in 1995 (Tomlinson, 2017), emphasizes tailoring teaching to meet diverse student needs. It aims to deepen learning for advanced students, encourage peer tutoring, and move beyond one-size-fits-all methods. Key strategies include focusing on big ideas, using prior assessments, and providing student choice (Boelens et al., 2018). Prior assessment evaluates students' dominant intelligences, grouping them into musical, interpersonal, and naturalist categories, which shape lesson design. This study emphasizes content, process, and product differentiation, tailoring vector learning materials to each intelligence type. Howard Gardner's multiple intelligences theory identifies eight types: logical-mathematical, verbal-linguistic, visual-spatial, musical, kinesthetic, interpersonal, intrapersonal, and naturalist, highlighting how individuals solve problems and create outcomes. (Anandarasu & Vaiyadurai, 2018; Neupane et al., 2018).

This research used a Multiple Intelligences questionnaire adapted from Dr. Terry Armstrong's assessment on the website: https://www.literacynet.org/mi/. The questionnaire is recognized for its reliability, as Dr. Armstrong is a trained clinician and scientist who led the Patient Outcomes Research Program at the Neuro-Oncology Branch (NOB). Students aged 8-16 are required to answer only the red questions, while those over 16 have additional blue questions (Wiliński & Kupracz, 2020). As a result, this questionnaire is believed to be suitable for identifying the dominant intelligence types in 10th-grade high school students. The grouping strategy aims to have 5-7 students per group. When three students within a group exhibit different dominant intelligences, the teacher will reassess to identify their second most dominant intelligence. Students are divided into groups during the lessons based on their primary intelligence types.

Improving class-wide achievement through individualized approaches is challenging (Smale-Jacobse et al., 2019). Differentiated instruction addresses diverse learning needs by grouping students based on dominant intelligences, but teachers need not incorporate all eight intelligences into their lesson plans (Bajaj & Sharma, 2018). Adaptivity is crucial in this approach, tailoring tasks to individual needs, such as prior knowledge and learning speed (García-Redondo et al., 2017). In the first meeting of the musical group, students worked on five other vectors with

the help of an example of one way to write vectors. This means that students can easily follow the work examples presented. However, the musical group students did not explain unit vectors. The student ability level differed in other groups; the naturalist group students could write three vectors correctly and identify vectors based on the types of vectors.

Vector-writing tasks in the student worksheet reflect differentiated instruction through parallel tasks tailored to students' intelligence types. For example, the musical group solved a problem about students traveling to an arts performance, while the naturalist group tackled a scenario involving boats and rocks. Parallel tasks address varying developmental levels while focusing on the same core concept, enabling simultaneous class discussion (Small, 2017). The question bbelow is a critical thinking question designed for musical, interpersonal, and natural groups.

The learning plan is designed not to completely differentiate between content, process, and product. The learning activities occur in three distinct locations: the classroom and the schoolyard. Didactic material for teaching vectors using differentiated instruction, focusing on defining vectors in a two-dimensional plane and teaching vector addition through the parallelogram rule can be sorted as in Table 7.

Table 7. Didactic vector learning material for differentiated instruction

| | **Musical Group** | **Interpersonal Groups** | **Naturalist Group** |
|---|---|---|---|
| Process | - Students solve a roadmap problem to an art performance on Google Maps<br>- Work in groups while listening to music | - Students solve problems in a ball game on tiled paper<br>- Play with tiled paper and small balls twisted from paper | - Students solve real problems on nature and visible images<br>- Learn outside the classroom by observing images of nature and tangible examples that appear |
| Product | Simple song lyrics | The results of the discussion in the form of photos/images | The results of nature observations, either directly or by pictures |

Table 7 shows that students with naturalist intelligence can solve nature-related problems. They learn best when engaging with nature, exploring living organisms, and studying plants and natural events (Denig, 2004). Although the three types of the student worksheets are designed with different intelligences, the primary goal of the lesson remains focused on the subject matter. The theory of multiple intelligences aims to enhance students' understanding of the content (Lunenburg & Lunenburg, 2014).

*The Influence of DI on Students' Critical Thinking and Self-Efficacy*

This research found differences between the results or findings and previous publications by other researchers. The relationship is a significant positive relationship between student self-

efficacy and critical thinking (Dehghani et al., 2011; Muhtadi et al., 2022), and students who have high self-efficacy can fulfill all indicators of critical thinking abilities, including focus, reasons, conclusions, situations, clarity, and overview (Syarifah et al., 2019). This finding is not in line with all that; students with high critical thinking skills cannot be guaranteed high self-efficacy.

These findings also call attention to the need to consider other studies in critical thinking. Students in the experimental class who received differentiated instruction showed improvements in their critical thinking abilities, aligning with previous research (Al-Shehri, 2020). Students who experienced demonstrated better critical thinking skills in mathematics compared to those who received traditional instruction (Lailiyah, 2016), along with greater independence (Maulidiya et al., 2019) and improved critical thinking in science (Al-Shehri, 2020). The students' answers were relatively diverse, with four test questions to measure students' critical mathematical thinking skills according to the specified indicators.

Critical mathematical thinking, as outlined in the CT3 indicator, requires presenting arguments and offering alternative solutions to identify errors. Learning styles also influence accuracy, with kinesthetic learners being more thorough than auditory and visual learners (Hananto et al., 2018). However, control class students struggle with problem-solving, which lacks the use of length concepts for calculation. The mistakes made by students are the same as mistakes in general regarding notation, x and y components, writing, and sketching vectors. Students would neglect the negative sign, they would include unit vectors in their answers (2j), and students were asked to solve -3i+2j vector presented graphically, some students often make mistakes in writing vectors (Barniol & Zavala, 2014). Some students gave good arguments but were incorrect in sketching the problem.

Critical thinking in mathematics requires visualizing situations and using mathematical reasoning (The Ontario, 2020). The topic of vectors demands critical thinking skills, as students must be able to solve problems both in textual form and through visual representation. Explaining the conclusion of the completion that has been carried out with the right reasons, meaning that students can understand concepts and complete mathematical calculations but have not met the fourth indicator of critical thinking ability. However, in other conditions (students in the musical learning group), it was found that students could explain the conclusion accompanied by the right reason.

Self-efficacy predicts student engagement and exam performance, but its impact on academic outcomes varies by level (Galyon et al., 2012). This study found improved critical mathematical thinking, but differentiated instruction did not influence self-efficacy development. Based on the results, four out of 35 students were classified in the very high or high categories for both critical thinking and self-efficacy. These results do not support the assumption of the

Bandura hypothesis that vicarious experiences are a source of self-efficacy. It was found that successful student test results (in terms of academics) significantly improved self-efficacy (Kudo & Mori, 2015). However, the increase in self-efficacy was not represented in paired or grouped students. Learning with differentiated instruction is grouped based on different types of intelligence and diverse cognitive abilities.

Improving students' self-efficacy requires a longer period. This is consistent with findings from other studies, which suggest that achieving goals in the affective domain is possible but requires a time-intensive process, especially for higher levels of affective development (Wu et al., 2019). The limited impact of the learning approach on self-efficacy is likely due to the study's short duration of less than two months. Achieving effective learning goals often requires more time, especially at higher levels. Other factors, such as student anxiety, which inversely correlates with self-efficacy (Kurland & Siegel, 2016), may have influenced the results. Consequently, the differentiated instruction approach did not significantly improve self-efficacy in this study.

## Conclusion

Overall, the results of this study indicate that differentiated instruction influences students' achievement in solving mathematical problems by promoting critical thinking. Critical thinking is considered one of the capabilities that can contribute to students' improved ability to overcome various mathematical problems, thus requiring encouragement from teachers to improve. Based on the results of this research, Differentiated instruction can play a significant role in improving a student's critical thinking abilities. The findings suggest that different instruction should be implemented in schools as much as possible to enhance students' critical thinking. The advantages of applying various instruction approaches to vector learning are that the learning design meets each student's needs (the student's dominant intelligence), maximizes the quality of student learning, and makes students more involved and focused in the class.

This study was conducted within a limited scope. Therefore, future research should focus on expanding the study scope. The limitations of this study include: 1) The limited research timeframe and schedule, as the study focused on class X (tenth-grade) mathematics students learning vector material in the even semester, which may have impacted the results. The relatively short duration of the research (less than two months) is a key factor in the lack of impact on self-efficacy. 2) The learning environment did not fully accommodate the needs of three distinct learning groups: musical, interpersonal, and natural. Having musical and interpersonal groups in the same room led to discomfort, which may have affected student participation. Therefore, future studies should explore other methods to enhance critical thinking and develop students' knowledge.

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