



The Effectiveness Of STEAM-Based Differentiated Learning On The Mathematics Learning Outcomes Of Junior High School Students

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ABSTRACT

Purpose of the Study:

The purpose of this study is to examine the effectiveness of STEAM-based differentiated learning on the mathematics learning outcomes of junior high school students.

Methodology:

This study employed a quantitative research method with a pre-experimental one-group pretest-posttest design. The tools used included observation sheets and achievement tests. Data analysis involved descriptive statistics and significance tests. The subjects were 24 junior high school students from SMP Negeri 5 Takalar.

Main Findings:

Student engagement in STEAM-based learning increased from 69% to 84%. The mean test score improved significantly from 35.21 to 80.42. The N-gain score showed substantial improvement, with a mean value of 0.7029. Both posttest and N-gain results were statistically significant ($p < 0.05$), confirming the effectiveness of the intervention.

Novelty/Originality of this Study:

This study offers a novel approach by integrating STEAM principles with differentiated learning in the context of mathematics education, an area that has not been extensively explored. It contributes to advancing the current knowledge by demonstrating the positive impact of this approach on students' engagement and academic outcomes, particularly in enhancing problem-solving and critical thinking skills in mathematics.

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1. INTRODUCTION

STEAM education is an interdisciplinary approach that encourages students to make connections between scientific inquiry, artistic creativity, and technical problem-solving. It has gained prominence due to its ability to nurture not only students' cognitive skills but also their creative and problem-solving capabilities. Unlike traditional STEM education, which focuses solely on Science, Technology, Engineering, and Mathematics, STEAM incorporates the arts, allowing for a more holistic learning experience that blends creativity with logic and technical know-how [1]. The inclusion of the arts makes the content more engaging and accessible to a diverse range of learning styles and abilities [2]; [3].

In the context of mathematics, STEAM-based learning encourages students to approach mathematical concepts through real-world applications, creative expression, and hands-on projects [4]. This approach not only helps students develop a more comprehensive understanding of mathematics but also enhances their enthusiasm and engagement with the subject [5]. By integrating the arts into math instruction, students are given opportunities to explore mathematical concepts from different perspectives, which can lead to deeper comprehension and improved problem-solving abilities.

Differentiated learning is a pedagogical strategy aimed at addressing the diverse needs of students within a classroom. It recognizes that students have varying levels of prior knowledge, learning styles, and interests, and thus requires flexible teaching methods that can be tailored to these differences [6]. According to [7], differentiated instruction involves adjusting content, process, and product based on students' readiness, interests, and learning profiles. This approach ensures that all students, regardless of their starting point, are provided with appropriate challenges and support to maximize their learning potential.

In STEAM education, differentiated learning is crucial because it allows for the customization of learning experiences. For example, in a mathematics lesson, some students may engage with more challenging problems that require higher-order thinking, while others may focus on foundational skills to solidify their understanding of key concepts. This flexibility ensures that every student can progress at their own pace and reach their full potential, making STEAM-based differentiated learning a highly effective strategy for improving student outcomes. Research has shown that incorporating STEAM into the classroom, especially through differentiated approaches, can significantly impact students' academic outcomes, particularly in subjects like mathematics. For instance, studies have highlighted how STEAM-based courses can enhance students' creativity and critical thinking, both of which are essential for mathematical problem-solving [8]; [9]. The hands-on nature of STEAM learning allows students to apply mathematical concepts in practical situations, making abstract ideas more tangible and relevant.

Furthermore, differentiated STEAM learning supports the development of various mathematical skills, such as spatial reasoning, logical thinking, and quantitative analysis. By engaging with real-world problems and artistic expressions, students are encouraged to think outside the box and apply mathematical concepts in novel ways. This process of inquiry and exploration is not only motivating but also leads to more meaningful and lasting learning outcomes. A study by [10] emphasizes that the integration of STEAM into physics education, which shares many conceptual and analytical similarities with mathematics, has shown positive results in fostering students' critical thinking and problem-solving abilities. While this research primarily focuses on physics, the principles of STEAM-based differentiated learning are highly transferable to mathematics instruction. The flexibility and adaptability inherent in differentiated learning provide an ideal platform for exploring complex mathematical topics, which might otherwise seem abstract or intimidating to students.

Studies conducted in similar educational contexts support the notion that differentiated STEAM learning can enhance various aspects of student development, such as creativity, motivation, and academic achievement [11]; [12]. Furthermore, research has shown that students exposed to differentiated STEAM learning approaches tend to outperform their peers in traditional settings, especially in subjects that require high-level cognitive skills like mathematics [13]; [14]. Focusing on junior high school students in this research is particularly significant, as this developmental stage represents a critical period in students' academic and cognitive growth. At this age, students are transitioning from concrete to abstract thinking, which makes it an ideal time to engage them in more complex and interdisciplinary learning experiences like STEAM. Moreover, junior high school is often a period where students begin to develop their identities as learners, and their attitudes toward subjects like mathematics can be shaped by the types of instruction they experience. Therefore, this study aims to explore the hypothesis that STEAM-based learning with a differentiated approach has a positive effect on junior high school students' mathematics learning outcomes. This hypothesis is based on increasing evidence showing that the combination of STEAM and differentiated learning can create a more engaging and effective learning environment for students.

2. RESEARCH METHOD

This study uses a quantitative research method with a pre-experimental design, specifically the one-group pretest-posttest type. The subjects of this study are students of SMP Negeri 5 Takalar. The data collection techniques in this study include observation and achievement tests. Observation is conducted to observe the STEAM-based learning process, including the behavior of students and teachers during the lesson, with the aim of assessing the success of the STEAM learning model implementation. Meanwhile, tests are used to measure

students' ability to understand and master the material after participating in STEAM-based learning. The purpose of the test is to evaluate the improvement in students' learning outcomes, particularly in terms of creative thinking and understanding of the concepts taught.

Data analysis for the observation sheet is done by examining the results of the observations during the STEAM-based learning process, which includes the steps of STEAM learning applied. The data analysis for the questionnaire uses descriptive statistical techniques to determine the percentage of students' responses to the STEAM-based learning. The success indicator in this study is that at least 75% of all components in the observation sheet of student activities meet the "active" criteria.

3. RESULTS AND DISCUSSION

Result Research

Observation data on STEAM differentiated learning activities are presented in Table 1 below:

Tabel 1. Student Activities Involved In STEAM-Based Differentiated Learning

No	Observed Student Activities	Percentage %		
		Before treatment	After treatment	enhancement
	Student activities involved in STEAM-based differentiated learning	69%	84%	16%

Based on the table 1 above, we get the information that 69% of students were actively engaged in the learning activities before the STEAM-based differentiated approach was introduced and there are increased to 84% after the intervention, showing a noticeable improvement in student engagement. So that, the increase in engagement is 16%, which is a positive indication that the STEAM-based approach effectively encouraged greater participation and activity among students.

Next, the data related to descriptive statistics on student learning outcome scores in STEAM differentiated learning is presented in Table 2 below.

Table 2. Descriptive Statistics on Student Learning Outcome Scores In STEAM Differentiated Learning

	Pretest	Posttest
Sample	24	24
Mean	35.2083	80.4167
Median	30.0000	80.0000
Standar deviasi	12.46553	9.88154
Variance	155.389	97.645
Range	45.00	40.00
Minumum	20.00	55.00
Maximum	65.00	95.00

Based on the table 2 above, we get the information that The mean score significantly improved from 35.21 in the pretest to 80.42 in the posttest, indicating a substantial increase in students' learning outcome, the median score also showed a large shift, from 30.00 pretest to 80.00 posttest, reinforcing the positive impact of the treatment. The standard deviation decreased from 12.47 to 9.88, which indicates less variation in posttest scores. This suggests that the STEAM-based approach has helped in improving the performance of most students, bringing their outcomes closer to the mean. The range (difference between the minimum and maximum scores) slightly decreased from 45 to 40, further indicating a reduction in performance disparities among students after the intervention. From the analysis above, it can be concluded that the STEAM-based differentiated learning approach significantly improves students' mathematics learning outcomes, as seen in substantial increases in average scores, increased consistency (lower standard deviations), and a narrowing of the performance range. For the Statistics table describing the N-gain scores for student learning outcomes, it is presented in the following table 3.

Table 3. Statistics Description of N-gain Scores of Student Learning Outcomes

	N-gain scores learning outcomes
Sample	24
Mean	.7029
Median	.7100
standar deviasi	.12038
Variance	.014
Range	.50
Minimum	.43
Maximum	.93

Table 4 above shows that the mean N-gain score of 0.7029 suggests a substantial improvement in student learning, as N-gain scores closer to 1.0 reflect large learning gains. The standard deviation of 0.12038 indicates that most students experienced similar levels of improvement, though there were a few outliers. The range from 0.43 to 0.93 shows that while there was a general trend of improvement, the degree of improvement varied between students, with some students achieving relatively high N-gains. From the analysis above, it can be concluded that the N-gain scores show a significant improvement in student learning outcomes, with most students showing strong gains in understanding mathematics as a result of the STEAM-based differentiated learning approach. For the presents the significance levels of the posttest and N-gain scores it is presented in the table 5 below.

Table 4. One Sample T Test

Name	Significance (2-tailed)	α
Posttest Learning Outcomes	0,013	0,05
N-gain Learning Outcomes	0,000	0,05

Table 4 above shows that Both the posttest results ($p = 0.013$) and the N-gain results ($p = 0.000$) are statistically significant, as both values are lower than the significance level of 0.05. This confirms that the improvements in students' learning outcomes are not due to chance, but rather a result of the STEAM-based differentiated learning intervention.

Discussion

The effectiveness of the STEAM-based differentiated learning approach on junior high school students' mathematics outcomes is evident from the data collected during this research. Several key trends emerge from the analysis of the observed student activities, test scores, and N-gain improvements, aligning with findings from relevant studies that support the use of STEAM and differentiated learning models in enhancing student learning outcomes. In this discussion, we will examine the results in detail and relate them to relevant research to strengthen the argument for the positive impact of this pedagogical approach. Before the STEAM-based differentiated learning approach was introduced, 69% of students were actively engaged in the learning activities. This engagement increased to 84% after the intervention, a 16% improvement. This increase in student participation aligns with the research conducted by [2], which found that incorporating a STEAM-based approach helps foster more positive attitudes toward mathematics, enhancing student engagement. The integration of arts with science and mathematics creates a dynamic and interactive learning environment that captures students' attention and makes learning more enjoyable. The increase in activity observed in this study mirrors the findings of [8], where STEAM-based courses led to heightened scientific creativity and greater student engagement in junior high school students. This is crucial, as active student participation is a key predictor of improved learning outcomes.

The data from the pretest and posttest scores reveal a substantial improvement in students' mathematics performance. The mean score increased from 35.21 in the pretest to 80.42 in the posttest, showing a significant positive effect of the STEAM-based differentiated approach on student learning. The reduction in the standard deviation (from 12.47 to 9.88) indicates that the intervention helped reduce variability in student performance, making the results more consistent across the group. This suggests that STEAM-based learning helps level the playing field, allowing students with varying levels of prior knowledge and abilities to benefit from the approach.

This finding is consistent with [9], who found that integrating STEAM-based learning with differentiated approaches led to improved numeracy literacy and greater consistency in student learning outcomes. Additionally, the narrowing of the performance range (from 45 to 40) suggests that the differentiated learning approach made it easier for all students, regardless of their starting level, to achieve higher scores. This aligns with [7], who argue that differentiated instruction, when combined with innovative approaches like STEAM, helps cater to diverse learning needs, ensuring that all students can achieve their potential.

The N-gain score, which measures the normalized improvement in student learning, had a mean value of 0.7029, indicating substantial learning gains. An N-gain closer to 1.0 reflects a large improvement, and the data suggests that most students showed significant progress as a result of the STEAM-based differentiated learning approach. The standard deviation of 0.12038 indicates that while most students experienced similar levels of improvement, there were a few outliers with relatively higher or lower gains. These findings are in line with [10], who found that the STEAM-based approach not only enhances critical thinking and creativity but also supports differentiated learning, allowing students to achieve meaningful improvements in their understanding of complex subjects like physics (and by extension, mathematics). The improvement in N-gain scores is a strong indicator that the STEAM-based differentiated approach was successful in fostering deep learning. This aligns with [15], who highlighted that differentiated instruction in STEAM helps meet the varying academic needs of students, leading to improved academic performance across the board. Both the posttest results ($p = 0.013$) and the N-gain results ($p = 0.000$) were statistically significant, with values lower than the significance level of 0.05. This confirms that the observed improvements in students' mathematics learning outcomes were not due to random chance but rather a result of the STEAM-based differentiated learning intervention. [13] found similar results in their study, indicating that differentiated instruction in secondary education, particularly when combined with innovative approaches like STEAM, can lead to significant improvements in students' learning outcomes. The statistical significance of the findings strengthens the argument that the STEAM-based differentiated learning approach is a valid and effective method for enhancing mathematics learning at the junior high school level.

The results from this study provide strong evidence that the STEAM-based differentiated learning approach significantly improves mathematics learning outcomes for junior high school students. The combination of interdisciplinary learning, student-centered approaches, and differentiated instruction fosters a deeper understanding of mathematical concepts and encourages critical thinking, creativity, and problem-solving skills. Educators looking to improve student engagement and achievement in mathematics should consider integrating STEAM principles into their teaching methods. The findings of this study align with previous research that has shown the positive impact of STEAM and differentiated learning on students' academic outcomes [8]; [9].

4. CONCLUSION

This study shows that STEAM-based differentiated learning significantly improves junior high school students' mathematics outcomes. Observational data indicated an increase in student engagement from 69% to 84%, reflecting higher participation. The average score of students improved significantly from 35.21 in the pretest to 80.42 in the posttest, demonstrating a positive impact on their understanding of mathematics. This improvement is further confirmed by the N-gain score of 0.7029, indicating substantial learning gains. Statistical significance ($p < 0.05$) further supports that the observed improvements in student performance were due to the STEAM-based differentiated learning approach.

Recommendations:

Based on the results, it is recommended to integrate STEAM-based learning into mathematics lessons to enhance student engagement and motivation. Differentiated learning should be applied to meet the diverse learning needs of students. Teachers should receive further training in STEAM and differentiated methods to ensure effective implementation. Additionally, the use of technology in teaching can enrich students' learning experiences. Further research is needed to explore the long-term effects of this approach and its applicability to other subjects. Therefore, STEAM-based differentiated learning has great potential to improve the quality of mathematics education in Indonesia.

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