



Integration of technology in differentiated learning to improve student learning outcomes in elementary school

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ABSTRACT

This study aims to measure the impact of technology integration in differentiated learning on student learning outcomes in elementary school. Using a quantitative experimental design with a pre-test post-test approach, this study involved 120 students of School 231 Sukaasih who were divided into two groups: an experimental group that used technology in differentiated learning and a control group that used traditional methods. Data was collected through pre-test, post-test, and student engagement questionnaires. Data analysis was conducted using t-tests for group comparison and linear regression to analyze the relationship between student engagement and learning outcomes. The results showed that the experimental group experienced a significant improvement in learning outcomes, with a higher average post-test score than the control group. In addition, higher student engagement in technology-based learning was positively associated with improved learning outcomes. These findings indicate that the use of technology in differentiated learning can improve students' understanding of the material and increase their engagement in the learning process. The implication of this study is the importance of integrating technology in education to improve the quality of learning, but this requires infrastructure support and training for teachers to maximize its benefits.



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INTRODUCTION

Education in the 21st century faces great challenges in dealing with the diversity of students, both in terms of abilities, learning styles, and interests. One of the approaches that is increasingly being applied in various countries to overcome these differences is differentiated learning (Pitaloka & Arsanti, 2022). This learning aims to provide a more personalized learning experience and in accordance with the individual needs of students, so that all students can develop according to their potential (Farid et al., 2022). In an effort to optimize differentiated learning, educational technology offers a wide range of opportunities. Technology, with its various digital platforms and tools, allows for more flexible and responsive teaching to the needs of diverse students, both in terms of learning speed, learning style, and the level of difficulty of the material being studied (Syamsuar & Reflianto, 2019).

However, while the potential of technology to support differentiated learning is enormous, its implementation is often hampered by several issues. Many schools, especially in areas with limited infrastructure, have not been able to make optimal use of technology (Firdaus & Ritonga, 2024). In addition, most teachers are also not fully skilled in integrating technology into their learning process. This makes technology, which should be able to improve the quality of learning, has not had a significant impact on student learning outcomes (Salsabila et al., 2021). In this context, a more targeted approach is needed to optimize the use of technology in differentiated learning, in order to overcome these challenges and achieve better learning outcomes for students.

One of the solutions that can be implemented is the integration of technology in differentiated learning. Technology allows teachers to provide materials that are appropriate to each student's ability level and learning style, as well as provide faster and more personalized feedback (Greco, 2023). Platforms like Google Classroom, Kahoot, and Edmodo can be used to make the learning process more interactive and allow students to learn in a more enjoyable way (Selfa-Sastre et al., 2022). Additionally, artificial intelligence (AI)-based technologies can help tailor learning challenges to students' abilities, provide a more personalized experience, and increase student engagement in learning (Ng et al., 2024).

Research on the use of technology in differentiated learning has begun to be carried out, but there is still a small amount of research that specifically examines the integration of technology in differentiated learning in Indonesia (Cakranegara, 2021; Karim et al., 2018; Ria & Mukhibat, 2020). Many previous studies have addressed technology in general or differentiated learning separately, without looking at the two at the same time. Most of the research also focuses more on the use of technology in teaching as a whole, and not much has addressed its impact on student learning outcomes in a context that is more focused on the diversity of student needs. Therefore, this study tries to fill this gap by examining the impact of the use of technology in differentiated learning on student learning outcomes in Indonesian schools.

This study aims to measure the impact of the use of technology in differentiated learning on student learning outcomes with two main objectives. First, to measure the difference in learning outcomes between students who use technology in differentiated learning and students who use traditional learning methods, using pre-test and post-test data. Second, to analyze the relationship between student engagement in technology-based learning and improved their learning outcomes, which will be analyzed through regression statistical techniques.

METHODS

Research Design

This study uses a quantitative experimental design with a pre-test post-test control group approach. The design involved two groups of students: an experimental group that would receive differentiated learning interventions with technology support, and a control group that would follow learning with conventional methods without technological support. This study aims to measure the difference in learning outcomes between the two groups before and after the intervention was carried out. Using pre-test and post-test, this study will identify changes in student learning outcomes caused by the integration of technology in differentiated learning.

Participants

This research was conducted at 231 Sukaasih Elementary School which was selected based on their readiness to provide access to technology and support for the use of technology in learning. These schools represent different levels of infrastructure and different technological facilities. The study participants consisted of 120 students, who were divided into two groups: an experimental group of 60 students and who would receive differentiated learning with technology, and a control group of 60 students and who would follow learning with traditional methods. Participant selection was done at

random, taking into account factors such as similarities in students' initial ability levels and their willingness to participate in the research.

Data Collection Instruments

The data in this study was collected using two main instruments: Pre-test and Post-test: This test is used to measure students' understanding of the learning material. The pre-test is given before the learning starts, while the post-test is given after the learning is over. This test is designed to measure changes in students' understanding of the material being taught, as well as to compare learning outcomes between the experimental group and the control group. Student Engagement Questionnaire: This questionnaire uses a Likert scale to measure the level of student engagement in technology-based learning. This questionnaire consists of 10 questions that assess various aspects, such as motivation, interaction with learning materials, and students' perceptions of the use of technology in learning. This questionnaire is given after the learning session is over to evaluate how technology affects student engagement.

Research Procedure

The research procedure began with the administration of a pre-test to both groups of students to measure their basic knowledge before the intervention began. Afterwards, the experimental group was given differentiated learning using technologies, such as Google Classroom, Kahoot, and artificial intelligence (AI)-based apps, for six weeks with a duration of two hours per meeting. In this learning, students can access learning materials tailored to their respective abilities and get feedback directly.

Meanwhile, the control group followed learning with conventional methods without using technology. The material given to both groups is the same, but the way of delivery and interaction with the material is different. After the learning is over, a post-test is given to measure changes in student learning outcomes. In addition, student engagement questionnaires were also distributed to find out how students felt about their experiences in technology-based learning. During the learning process, the researcher also made observations to record students' interactions with technology and with fellow students. These observations provide further insight into how effectively technology is used in supporting differentiated learning and increasing student engagement.

Data Analysis Techniques

Data collected from pre-test, post-test, and student engagement questionnaires will be analyzed using two main analysis techniques: T Test (Independent Samples T-Test): The t-test is used to measure differences in learning outcomes between the experimental group and the control group by comparing the average post-test scores of each group. The test aimed to test whether there was a significant difference between the two groups after the learning intervention. Linear Regression: To analyze the relationship between student engagement in technology-based learning and improved learning outcomes, linear regression will be used. This technique aims to find out whether higher engagement rates can predict improved student learning outcomes as measured through changes in pre-test and post-test scores.

RESULTS

Measuring the Difference in Learning Outcomes between the Experimental Group and the Control Group

To measure the difference in learning outcomes between the experimental group and the control group, data collected through pre-test and post-test were analyzed. This test aims to evaluate the improvement of students' understanding of the material that has been taught, both in the group that uses technology in differentiated learning (experimental group) and the group that uses traditional methods (control group).

Table 1. Average pre-test and post-test scores

Groups	Average Pre-test Score	Average Post-test Score	Standard Deviation Pre-test	Standard Deviation Post-test
Eksperimen	65	80	10	8
Controls	60	70	12	10

The Experiment group that used technology in differentiated learning showed a significant increase from 65 on the pre-test to 80 on the post-test, with an increase of 15 points. This shows a substantial improvement in students' understanding of the material after receiving technology-based learning. The control group, which used traditional learning methods, saw a smaller increase from 60 on the pre-test to 70 on the post-test, with an increase of 10 points. Although there was an improvement, this increase was smaller when compared to the experimental group.

The difference in improvement between the two groups shows that the use of technology in differentiated learning has a greater impact on student learning outcomes. The T (Independent Samples T-Test) confirmed that the difference between the experimental group and the control group was statistically significant ($p < 0.05$), which showed that the integration of technology had a positive effect on improving student learning outcomes.

Analyzing the Relationship between Student Engagement in Technology-Based Learning

To analyze the relationship between student engagement in technology-based learning and the improvement of their learning outcomes, linear regression analysis was used. The student engagement questionnaire using the Likert scale (from 1 to 5) measures various aspects of engagement, such as motivation, activeness, and perception of the technology used in learning. Student engagement data was analyzed to identify whether higher engagement was associated with improved learning outcomes.

Table 2. The Relationship Between Engagement Levels and Learning Outcomes

Groups	Average Engagement (Scale 1-5)	Average Pre-test Score	Average Post-test Score	Engagement vs. Improved Learning Outcomes (Regression Coefficient)
Eksperimen	4.2	65	80	0.58**
Control	3.1	60	70	0.33

The Experiment Group had an average student engagement of 4.2 on the Likert scale (indicating a high level of engagement). Linear regression analysis showed that higher levels of engagement in technology-based learning were associated with greater improvements in learning outcomes, with a significant regression coefficient of 0.58 ($p < 0.05$). This indicates that student engagement in technology-based learning has a strong impact on improving their learning outcomes. The Control Group, with an average engagement of 3.1, showed lower engagement. Despite the improvement in their learning outcomes, the regression coefficient for engagement to improved learning outcomes was 0.33, suggesting that the association between engagement and learning outcomes in the control group was weaker. These results confirm that higher student engagement in technology-based learning contributes to a more significant improvement in learning outcomes. Therefore, high engagement in the learning process is essential, and technology can be an effective tool for increasing student engagement.

The results of this study show that the integration of technology in differentiated learning can significantly improve student learning outcomes. The experimental group that used technology in differentiated learning experienced a greater improvement in learning outcomes compared to the control group that used traditional learning methods. In addition, the results of linear regression analysis showed that student engagement in technology-based learning was positively related to improved their learning outcomes, indicating that technology not only improved learning outcomes, but also increased student engagement in the learning process.

DISCUSSION

This research reveals that the integration of technology in differentiated learning has a significant impact on student learning outcomes. The results found in the field, namely a greater increase in post-test scores in the experimental group compared to the control group, reflect the effectiveness of technology in supporting personalized learning. In a global context, this research is in line with various studies that have been conducted in developed countries, where technology has been applied to tailor teaching to the individual needs and abilities of students (Abidin et al., 2021; Engelbertink et al., 2021). The application of technology in differentiated learning is not only relevant for Indonesia, but also in line with global education trends that prioritize a more individualized approach to learning (Ng et al., 2024).

One of the important findings in this study is the difference in learning outcomes between the experimental group and the control group, which suggests that the use of technology in differentiated learning can significantly improve student learning outcomes. The experimental group, which used digital platforms such as Google Classroom, Kahoot, and artificial intelligence-based apps, experienced greater improvements in material understanding compared to the control group that only used traditional methods. This illustrates the importance of technology's role in creating more engaging and interactive learning, which encourages students to be more involved in the learning process (Nurtayeva et al., 2024). This increase in student engagement, as seen in the results of the student engagement questionnaire, also suggests that technology can help address the challenges of boredom and lack of motivation in conventional learning, which are often faced by students around the world (Lynch et al., 2024).

The results of linear regression analysis showing a strong relationship between student engagement levels and improved learning outcomes underscore the importance of active engagement in learning. Higher student engagement, which is reflected in their active interaction with technology and learning materials, is directly related to better learning outcomes. This confirms the finding that students' active involvement in the learning process is one of the most influential factors in improving academic outcomes (Zhang et al., 2017). At the global level, this approach also supports theories that prioritize student involvement as key to effective teaching, such as the constructivist model, which emphasizes the importance of active and collaborative learning experiences (Ndibalema, 2022).

A more significant improvement in learning outcomes in the experimental group could also be attributed to technological characteristics that allowed for more student-oriented learning. With technology, students can access learning materials according to their respective abilities and pace, providing a more personalized and relevant learning experience. Technology is used to accelerate the understanding of difficult concepts and provide instant feedback (Abidin et al., 2021). This has been shown to be effective in creating more flexible learning that can be tailored to individual students' needs, as well as encouraging improvement in overall learning outcomes (Wang et al., 2024).

In addition, the difference in standard deviation between the experimental group and the control group also provides insight into the effectiveness of technology-based learning in creating a more equitable learning experience. The experimental group, which had a smaller standard deviation on the post-test, showed that the use of technology tended to reduce the variation in learning outcomes between students. This means that technology can provide a more inclusive approach, where students with different abilities can access material that suits their level of understanding. At the global level, this reminds us of the importance of inclusive learning that enables all students, regardless of their background and ability, to learn effectively (Llamazares de Prado & Arias Gago, 2023; Sharma & Gupta, 2024).

Overall, the results of this study show that the integration of technology in differentiated learning has great potential to improve student learning outcomes, both at the national and global levels. Technology, when used appropriately, not only makes learning more engaging and interactive, but it

can also increase student engagement and provide a more personalized learning experience. However, to achieve the full potential of technology in education, supportive policies and investments in terms of infrastructure and teacher training are essential. As a developing country, Indonesia has great potential to utilize technology as a tool to create a more inclusive and quality education system, along with increasing global awareness of the importance of technology in supporting more effective and sustainable learning.

CONCLUSION

The integration of technology in differentiated learning has a significant impact on improving student learning outcomes, both directly and through increased student involvement in the learning process. The experimental group that used the technology showed a greater improvement in the understanding of the material compared to the control group that used traditional methods. Additionally, higher student engagement in technology-based learning has been shown to have a positive relationship with their learning outcomes, indicating that technology can create more interactive, personalized, and adaptive learning to students' individual needs. Therefore, the application of technology in differentiated learning has the potential to be an effective solution to improve the quality of education, but this requires policy support, adequate infrastructure, and teacher training to ensure its optimal utilization.

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