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The Effect of Adaptive Learning System Based on Flipped Classroom on Students' Learning Outcomes in Natural Sciences at SMP Negeri 3 Ma'rang

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Abstract : This study investigates the impact of an adaptive learning system based on the flipped classroom model on the learning outcomes of ninth-grade students in Natural Sciences at SMP Negeri 3 Ma'rang. Using a quasi-experimental design, the research compared an experimental group employing adaptive flipped learning with a control group using conventional methods. The results showed a significant increase in posttest scores for the experimental group (mean = 84.83) compared to the control group (mean = 69.25). The adaptive learning model encouraged personalized learning experiences and fostered student engagement. The normalized gain (N-Gain) of 43.6% for the experimental group indicates high effectiveness of the method.

Keywords: adaptive, learning, flipped, classroom, science education

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1. Introduction

The fast-paced development of digital technology in education has led to increased attention toward technology-integrated teaching models. Among these, adaptive learning systems combined with flipped classroom strategies have gained significant momentum due to their personalized nature and potential to enhance student academic achievement [1], [2].

The flipped classroom reconfigures traditional instruction by presenting new materials outside the classroom and utilizing in-class sessions for collaborative practice and teacher feedback [3]. When paired with adaptive learning — a method that modifies content based on students' learning progress — this model becomes even more effective in addressing diverse learning needs [4].

In junior high school, a crucial stage where students establish foundational scientific thinking, traditional methods often fail to cater to individual differences, leading to disengagement and inconsistent outcomes. Thus, integrating adaptive and flipped strategies offers a promising alternative to support inclusive, meaningful science education [5].

Adaptive systems track learner progress in real-time and adjust instructional content accordingly, enabling teachers to provide differentiated learning

experiences [6]. The flipped learning model complements this by promoting pre-class self-study followed by in-class interaction, supporting deeper understanding and critical thinking development [7], [8].

This research explores how such integration affects science learning outcomes in a ninth-grade context at SMP Negeri 3 Ma'rang. The study contributes to the discourse on inclusive, technology-enhanced pedagogy aligned with Indonesia's Merdeka Belajar curriculum [9].

2. Literature Review

Adaptive learning refers to the use of digital systems to tailor educational experiences based on individual learners' needs [10]. These systems leverage learning analytics to adjust materials in real-time, supporting a more personalized and effective approach to instruction [11]. Artificial intelligence technologies often power such systems, enabling dynamic responses to student inputs and recommending appropriate next steps [12].

The flipped classroom shifts direct instruction from the classroom to at-home learning via digital content, allowing in-class time for collaborative, active engagement [13]. This model emphasizes learner autonomy and preparation, as students are expected to engage with the material before class. Studies suggest that this approach enhances motivation, accountability, and depth of learning [14], [15].

Science education aims to cultivate not only conceptual knowledge but also critical thinking, problem-solving, and hands-on skills. Learning outcomes are typically classified into cognitive, affective, and psychomotor domains [16]. To maximize achievement across these domains, educators are encouraged to adopt constructivist and inquiry-based approaches that link theory to practice while maintaining high levels of student engagement.

3. Method

This study employed a quasi-experimental design utilizing a pretest-posttest control group approach. The experimental group received instruction through an adaptive learning system integrated with a flipped classroom model, while the control group followed conventional teacher-centered methods.

The participants were 49 ninth-grade students enrolled at SMP Negeri 3 Ma'rang. The sample was divided into two groups: 25 students in the experimental group and 24 in the control group. The selection was based on class grouping, with one class assigned as the experimental group and the other as the control group.

The main research instrument was a science learning achievement test, constructed to align with the national curriculum. The test was administered before and after the intervention to both groups to evaluate improvement in learning outcomes.

Students in the experimental group accessed instructional videos and digital materials prior to class meetings. Classroom sessions focused on problem-solving, peer discussions, and teacher-facilitated feedback. In contrast, the control group

descriptive statistics, including mean and standard deviation, were computed to summarize student performance. Inferential analysis using independent samples t-tests was conducted to determine statistical significance between groups. Additionally, normalized gain (N-Gain) scores were calculated to assess the relative improvement in learning outcomes.

4. Results and Discussion

Descriptive Statistics

Table 1. The following table presents the mean and standard deviation of pretest and posttest scores for both groups.

Group	N	Pretest Mean (SD)	Posttest Mean (SD)	N-Gain (%)
Experimental	25	63.52 (7.32)	84.83 (5.21)	43.6
Control	24	62.50 (6.91)	69.25 (6.73)	23.5

Inferential Analysis

An independent samples t-test revealed a statistically significant difference in the posttest scores between the experimental and control groups ($p < 0.05$), indicating that the adaptive flipped classroom approach contributed to improved learning outcomes.

Discussion

These results support the effectiveness of combining adaptive learning systems with flipped classroom strategies. The model allowed students to engage with instructional content at their own pace, which likely increased comprehension and retention. In-class activities further reinforced learning through collaborative discussions and immediate feedback [18].

The higher normalized gain in the experimental group reflects the model's ability to differentiate instruction according to student needs. These findings align with prior research highlighting improved critical thinking, learner autonomy, and engagement in adaptive and flipped environments [19].

From a practical standpoint, this approach presents a viable method for implementing Indonesia's Merdeka Belajar curriculum, which encourages flexible, student-centered learning practices.

5. Comparison

Previous studies have consistently demonstrated the effectiveness of flipped classrooms in improving students' motivation, critical thinking, and collaborative abilities. Similarly, adaptive learning systems have shown promise in enhancing academic performance, especially in language education contexts [20]. However, many of these studies have investigated these approaches independently, without examining their combined application—particularly within science education at the junior high school level.

This research differentiates itself by integrating adaptive learning with the flipped classroom model to optimize learning outcomes in science subjects. The approach not only personalizes content delivery but also enriches classroom interactions. This synergy addresses diverse learning needs while fostering greater engagement, making it a promising pedagogical strategy for the middle school context.

6. Conclusion

This study concludes that the implementation of an adaptive learning system based on the flipped classroom model significantly enhances students' academic performance in science. The combination of technology-driven personalization and interactive classroom activities offers a powerful framework for improving student outcomes.

The findings support the integration of such models in junior high school settings, particularly under the Merdeka Belajar curriculum, which emphasizes flexible and student-centered education. Future research should explore the long-term impact of this approach and assess its adaptability across different subjects and educational levels.

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