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Application of Machine Learning to Personalization of Adaptive Curriculum in Indonesian Middle Schools

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ABSTRACT
In recent years, there has been increasing interest in utilizing Machine Learning (ML) to personalize the learning experience in educational settings. The application of ML in middle school curriculums in Indonesia presents an opportunity to enhance adaptive learning models tailored to individual students' needs. This study aims to explore the potential of integrating ML algorithms to create a personalized, adaptive curriculum for middle school students. The primary objective is to evaluate how ML can optimize learning outcomes by adjusting content delivery based on student performance and learning patterns. Using a mixed-methods approach, the research combines qualitative data from educators and quantitative data from student performance metrics to design a model for adaptive learning. The ML algorithms used include decision trees, clustering, and reinforcement learning, which adaptively modify the curriculum based on real-time student feedback. The results show a significant improvement in student engagement and academic performance, with tailored content leading to better learning outcomes. The study concludes that ML-driven personalization can be effectively integrated into middle school curriculums, offering a scalable solution to enhance educational quality in Indonesia.

Keywords: *Adaptive Curriculum, Education Technology, Middle School*

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INTRODUCTION

The rapid advancements in technology have reshaped various sectors, including education, where the integration of artificial intelligence (AI) and machine learning (ML) has begun to show considerable potential (Odriozola-Olalde dkk., 2025; Yu dkk., 2025). Education systems worldwide, particularly in Indonesia, are undergoing substantial transformations aimed at improving teaching and learning processes. One such promising area is the development of personalized adaptive learning systems, which aim to cater to the diverse learning needs of students (Chu & Kurup, 2025; Dong, 2025). As the educational landscape shifts toward more dynamic and individualized learning environments, the role of machine learning in personalizing curricula for middle school students becomes increasingly important. The Indonesian educational system, however, faces several challenges in implementing such advanced technologies, given the need to

enhance the quality of education while addressing diverse student needs. Traditional approaches to curriculum design often fail to account for individual learning differences, resulting in a one-size-fits-all model that can limit student potential (Chun dkk., 2025; Tasliarmut dkk., 2025). By exploring the application of machine learning for adaptive curriculum personalization, this research delves into the potential to optimize learning experiences for Indonesian middle school students, ensuring that educational content is tailored to meet their specific needs.

The core issue addressed by this study lies in the limited application of technology to adaptively modify curriculum content according to the unique learning profiles of middle school students in Indonesia (Salonga dkk., 2025; Zhao dkk., 2025). Despite the growing interest in technology-driven education solutions, there is still a significant gap in understanding how machine learning can be practically implemented to foster personalized learning experiences. Indonesian middle schools, in particular, face a major challenge in utilizing technological advancements in education to optimize curriculum delivery. Students, especially in large classes, often struggle to keep up with the pace of instruction, leading to disparities in academic performance. Traditional teaching methods, which follow a standardized curriculum, may not address the varying levels of academic ability, prior knowledge, and learning styles present in classrooms (Kuralay dkk., 2025; Shi dkk., 2025). This research specifically tackles how machine learning can analyze students' learning behaviors, preferences, and academic progress in real-time to offer adaptive learning paths. The study aims to identify how machine learning techniques, such as clustering, classification, and reinforcement learning, can be integrated into the curriculum design process to offer a more personalized educational experience for each student.

This research aims to achieve several objectives. First, it seeks to demonstrate how machine learning algorithms can be used to personalize learning content in middle school classrooms (Ahmad dkk., 2025; Vorobyeva dkk., 2025). By adapting the curriculum based on the individual learning progress and needs of students, the goal is to create a more responsive and effective educational system. Secondly, the research endeavors to analyze how the adaptive learning model can improve academic outcomes for students in Indonesia, particularly by fostering engagement and better understanding of the material. Through the application of machine learning models such as decision trees, collaborative filtering, and reinforcement learning, the study will evaluate the feasibility and effectiveness of these algorithms in a real classroom setting (Balart & Shryock, 2025; Kansagra dkk., 2025). The research also aims to assess the scalability of such adaptive systems in the broader context of Indonesian middle schools, providing insights into the potential challenges and opportunities in implementing machine learning-driven curriculum personalization across various educational institutions. Ultimately, this study will provide practical recommendations on how machine learning can be successfully integrated into the existing curriculum structure to enhance learning outcomes and support teachers in delivering personalized education.

Despite a growing body of literature exploring adaptive learning and educational technology, a significant gap remains in the application of machine learning specifically tailored to middle school curricula in developing countries such as Indonesia (Bandarigodage dkk., 2025; Nwokolo dkk., 2025). While adaptive learning systems have been studied extensively in the context of higher education and in developed nations, their integration into middle school classrooms, especially in Indonesia, has not been explored in-depth. Most existing studies focus on generic adaptive learning models without considering the complexities and unique challenges faced by middle school students in Indonesia. Moreover, the integration of machine learning in the personalization of curriculum for this demographic is relatively under-researched. This study fills that gap by focusing specifically on the use of machine learning to develop adaptive learning pathways that are personalized to the individual needs of middle school students in Indonesia (He, 2025; Islam dkk., 2025). By addressing this gap, the research contributes valuable insights into the feasibility of adapting cutting-edge technology for personalized education in an Indonesian context, which is a crucial step towards improving educational outcomes in the country.

The novelty of this research lies in its application of machine learning techniques to personalize adaptive curricula in Indonesian middle schools, an area that has not been widely explored in existing literature (Awd & Walther, 2025; Barzegar dkk., 2025). While the concept of adaptive learning is not new, the integration of machine learning into this domain presents new possibilities for precision in curriculum design. What sets this research apart is the focus on a developing country context, specifically Indonesia, where educational technology has yet to reach its full potential in transforming traditional pedagogical models. The study's focus on middle school education further differentiates it, as most existing research centers around higher education. Additionally, the study's emphasis on real-time data collection from students' learning behaviors to adjust the curriculum dynamically introduces an innovative approach to personalized education (Dubey & Crevar, 2025; Mukkala dkk., 2025). This research is significant as it demonstrates the potential for machine learning to enhance the efficiency and effectiveness of educational systems in developing countries, particularly in addressing issues such as student engagement, academic disparities, and the one-size-fits-all curriculum model (Awd & Walther, 2025; Kansagra dkk., 2025). Therefore, the novelty and significance of this research lie not only in the application of machine learning but also in the contribution it makes to bridging the technological gap in the education sector in Indonesia.

In conclusion, this study seeks to address critical issues in the personalization of education by applying machine learning techniques to adaptive curricula in Indonesian middle schools. It aims to fill the existing gap in the literature, provide practical insights into the use of technology for personalized learning, and offer innovative solutions to improve student outcomes (Dubey & Crevar, 2025; Silva Bravo dkk., 2025). With the increasing role of AI and machine learning in various fields, this research is timely and essential in shaping the future of education in Indonesia.

RESEARCH METHODOLOGY

This study employs a mixed-methods research design, combining both qualitative and quantitative approaches to explore the application of machine learning in personalizing an adaptive curriculum for Indonesian middle schools. The research aims to evaluate the effectiveness of machine learning algorithms in adapting learning content based on individual student performance, preferences, and behavior (Supriya dkk., 2025; Zhuang dkk., 2025). A quantitative approach is used to collect data on student performance through pre-tests, post-tests, and real-time learning analytics, while qualitative data is gathered through interviews and focus group discussions with teachers and educational experts to gain insights into the challenges and opportunities of implementing such a system.

The population of this study consists of middle school students and teachers in selected schools across Indonesia, with a focus on urban and rural areas to ensure diverse representation (Li, 2025; Roodsari dkk., 2025). The sample includes 200 middle school students and 20 teachers from five different schools that are willing to participate in the study. The students are chosen based on varying academic abilities, while teachers are selected based on their experience with curriculum development and the use of technology in education (Chaudhry & Sharma, 2025; Geetha dkk., 2025). The sample is representative of the broader middle school population in Indonesia, ensuring that the findings of the study are generalizable to other schools with similar contexts.

The instruments used for data collection include machine learning models, questionnaires, and interview guides. The machine learning algorithms implemented for the personalized adaptive curriculum include decision trees, clustering, and reinforcement learning. These algorithms analyze student data in real-time and adapt the curriculum accordingly. Pre-test and post-test assessments are administered to measure changes in student performance before and after the intervention (Li, 2025; Molnár & Nagy, 2025). Additionally, surveys and questionnaires are distributed to students and teachers to gather their perspectives on the effectiveness and feasibility of the adaptive learning system. Semi-structured interviews and focus groups are conducted with teachers to understand their experiences and challenges with integrating machine learning into classroom teaching.

Procedures involve several phases: (1) Initial preparation, where schools and participants are selected and the necessary permissions are obtained; (2) Training of teachers and students on how to use the adaptive learning system and how data will be collected; (3) Implementation of the machine learning model in the classroom, where data is collected on student interactions with the adaptive curriculum; (4) Data analysis, where both quantitative and qualitative data are analyzed to evaluate the impact of the adaptive learning system on student performance; and (5) Final reporting, where results are compiled, conclusions are drawn, and recommendations are provided (Huang dkk., 2025; Meng, 2025). Throughout the study, ethical considerations are taken into account, ensuring confidentiality and informed consent from all participants.

RESULTS AND DISCUSSION

The dataset collected for this study includes a variety of variables that track student performance, behavior, and engagement within the personalized adaptive curriculum. Data was gathered through pre-tests, post-tests, and real-time student interaction with the machine learning-driven adaptive system. The pre-test scores reflected students' baseline knowledge, while post-test scores measured improvements after exposure to the personalized curriculum. Additionally, real-time data from the machine learning algorithms captured how students interacted with the adaptive learning materials. Table 1 below summarizes the key statistical results of the study, showing the average pre-test and post-test scores for all students, as well as the level of engagement across different learning modules.

Table 1: Summary of Student Performance and Engagement

Measurement	Average Pre-Test Score	Average Post-Test Score	Average Engagement Level (Scale: 1-5)
All Students (n=200)	65.4	82.7	4.2
Urban Students (n=100)	66.1	83.4	4.3
Rural Students (n=100)	64.6	81.8	4.1

The data shows a clear improvement in student performance after engaging with the personalized adaptive curriculum. The average increase in post-test scores across all students was 17.3 points, with urban students showing slightly higher improvement than their rural counterparts. The engagement levels also show a positive correlation with performance, with students who engaged more frequently with the system demonstrating better test results. This indicates that the machine learning-driven system not only improved academic performance but also fostered increased interaction with learning materials. The slight difference in performance between urban and rural students can be attributed to varying levels of access to technology and internet infrastructure in these regions.

The inferential analysis conducted using paired sample t-tests confirmed that the improvement in student performance was statistically significant ($p < 0.05$). The t-test comparison of pre-test and post-test scores for all students showed a marked difference, with a mean score increase of 17.3 points. This statistical result supports the hypothesis that machine learning applications in adaptive curricula can significantly enhance student performance. The p-value for engagement levels was also significant, further validating that higher levels of student interaction with the system correlate with better academic outcomes. The analysis indicates that the adaptive learning system had a measurable impact on student performance, with machine learning personalization contributing to this positive effect.

When examining the relationship between student engagement and academic performance, a moderate positive correlation was found ($r = 0.58$). This suggests that the more students engaged with the adaptive curriculum, the better their academic outcomes. Further analysis revealed that certain learning modules, particularly those focused on

mathematics and science, saw higher levels of engagement and improvement in test scores compared to other subjects. These findings suggest that the adaptive system's effectiveness may vary depending on the subject area and the individual student's learning needs. Additionally, the difference in engagement levels between urban and rural students points to external factors such as access to technology and the digital divide that may influence the overall success of the adaptive curriculum.

In the case study of one urban school, the adaptive curriculum was implemented in a 7th-grade science class with 30 students. The pre-test results indicated that students had a general understanding of basic scientific concepts, scoring an average of 68%. After 6 weeks of interaction with the personalized curriculum, post-test scores averaged 86%, with the highest individual improvement being 24 points. Notably, the teacher observed that students demonstrated more initiative in class discussions and showed a deeper understanding of scientific principles. The case study suggests that the personalized curriculum not only enhanced student performance but also increased engagement with the subject matter, which is critical for long-term retention and learning. This individual classroom example underscores the effectiveness of machine learning in adapting the curriculum to meet the diverse needs of students.

From the case study, it is evident that the adaptive system led to a marked improvement in student understanding and performance. Teachers reported that the system helped them identify students who were struggling and allowed them to provide targeted interventions. The adaptive system’s ability to offer personalized learning paths for each student helped address gaps in knowledge and catered to individual learning styles. Furthermore, the system's real-time feedback allowed teachers to monitor progress and adjust instructional strategies more effectively. This case illustrates the potential of machine learning to transform the learning experience in classrooms by creating a more responsive and individualized environment for students.

In summary, the data analysis demonstrates that the machine learning-based adaptive curriculum significantly improved student performance and engagement. The statistical and inferential analyses confirm that personalization through machine learning leads to measurable academic improvements. The relationship between student engagement and academic performance suggests that the more students engage with the adaptive system, the better their learning outcomes. The case study further supports the notion that the adaptive curriculum can be highly effective in real classroom settings. The findings of this study provide strong evidence that machine learning can be a powerful tool in personalizing education and enhancing student learning experiences in Indonesian middle schools.

The results of this study demonstrate a significant improvement in student performance and engagement after the application of a machine learning-driven adaptive curriculum in Indonesian middle schools. The data indicates an average increase of 17.3 points in post-test scores across all students, with urban students showing slightly higher improvements than rural students. Engagement levels were also positively correlated with academic performance, suggesting that higher interaction with the adaptive system led to

better learning outcomes. The results provide strong evidence that machine learning can effectively personalize curriculum delivery and foster a more engaging and responsive learning environment for students.

When comparing these findings to previous research, the results align with studies that highlight the potential of machine learning and adaptive learning systems in education. For example, studies by Pane et al. (2015) and Koedinger et al. (2013) have shown that adaptive learning systems can enhance student performance by tailoring content to individual learning needs. However, this study differs from others in its focus on middle school students in Indonesia, a developing country where access to technology and digital infrastructure may be limited. This study extends the body of knowledge by exploring the unique challenges and opportunities of applying machine learning in this specific context, especially in rural schools where technology adoption is still emerging.

The findings of this study suggest that the personalized adaptive curriculum driven by machine learning can serve as a turning point for education in Indonesia. It reflects a shift from traditional, one-size-fits-all teaching methods towards a more individualized and data-driven approach. This is a critical development, as it underscores the importance of adapting educational systems to meet the needs of diverse student populations. The results also signal the growing role of technology in enhancing educational equity, particularly in underserved areas. The ability to personalize the curriculum based on real-time student data can help bridge the gap between different levels of academic achievement, offering each student a tailored learning experience that suits their individual pace and style.

The implications of these results are far-reaching for the future of education in Indonesia. The study shows that machine learning can play a pivotal role in enhancing educational outcomes by providing personalized learning paths that cater to individual student needs. Schools across Indonesia, particularly in rural areas, can benefit from such adaptive learning systems, which can help address disparities in academic achievement. The use of machine learning also presents an opportunity for teachers to better monitor student progress and intervene more effectively, thus improving the overall quality of education. The findings suggest that embracing technology in the classroom is not just a matter of increasing engagement, but also a strategic approach to improving academic performance on a national scale.

The findings can be attributed to several factors. First, the machine learning algorithms used in the study effectively personalized the curriculum, allowing it to adapt to individual learning behaviors and performance levels. The real-time feedback mechanism in the system allowed students to work at their own pace, reinforcing concepts they struggled with while advancing through areas they had mastered. Second, the significant increase in performance and engagement can be linked to the way the system made learning more interactive and responsive to student needs, fostering a sense of ownership over their learning. Lastly, the difference in improvement between urban and rural students highlights the digital divide, suggesting that while technology has the

potential to enhance education, its effectiveness is influenced by the level of infrastructure and resources available in different regions.

Moving forward, the next steps should focus on scaling this adaptive learning model to other regions in Indonesia and refining the machine learning algorithms to ensure that the system is inclusive and adaptable to various educational contexts. Further research should explore how the system can be integrated into the broader educational framework and its long-term impact on student learning outcomes. Additionally, addressing the digital divide and ensuring equal access to technology in both urban and rural schools will be critical to ensuring that the benefits of adaptive learning are distributed equitably. The insights from this study provide a roadmap for future advancements in educational technology, paving the way for the wider application of machine learning in educational settings across Indonesia.

CONCLUSION

The most significant finding of this study is the clear and measurable improvement in student performance and engagement after the implementation of a machine learning-driven adaptive curriculum. This research contributes to the growing body of evidence supporting the use of machine learning in educational settings, particularly in a developing country context such as Indonesia. The data demonstrates that students who engaged with the personalized curriculum showed significant improvements in test scores and academic performance. Notably, the study also revealed that urban students had slightly better outcomes than their rural counterparts, highlighting the importance of addressing the digital divide in the application of such technologies.

This research offers valuable contributions in both conceptual and methodological areas. Conceptually, it provides a detailed exploration of how machine learning can be used to personalize and adapt curricula, ensuring that the educational experience is tailored to individual student needs. Methodologically, it introduces a practical approach for implementing machine learning algorithms in middle school classrooms and provides a framework for assessing their effectiveness. By combining both qualitative and quantitative data, this study offers a comprehensive view of how technology can enhance personalized learning in real-world educational settings, especially in schools with varying access to digital resources.

The study's limitations lie primarily in its focus on a limited number of schools, which may not fully capture the diverse challenges faced by middle schools across Indonesia. The sample size, while sufficient for initial insights, may not be representative of the entire population of middle school students, particularly in rural or remote areas with limited technological infrastructure. Furthermore, the study did not explore the long-term effects of personalized adaptive learning on student outcomes. Future research should expand the sample size and duration of the study to examine how these systems impact student performance over extended periods and explore how the adaptive learning model can be scaled to accommodate schools with different levels of technological access. Additionally, investigating the impact of teacher training on the successful implementation

of machine learning-based adaptive curricula would provide further insights into optimizing the use of technology in education.

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