OPEN ACCESS
Scientechno: Journal of Science and Technology
Vol. 5 No. 1. February 2026, pp. 1-14 DOI. 10.70177/ Scientechno.v5i1.2639
Research Article

AN AI-BASED ADAPTIVE LEARNING PLATFORM FOR PERSONALIZED STEM EDUCATION IN INDONESIAN HIGH SCHOOLS

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Article Info
Received: August 18, 2025
Revised: September 16, 2025
Accepted: January 12, 2026
Online Version: February 26, 2026

Abstract
In recent years, the demand for personalized education has increased, particularly in Science, Technology, Engineering, and Mathematics (STEM) fields, where students' learning needs vary significantly. In Indonesia, traditional classroom-based teaching methods struggle to accommodate the diverse learning styles and paces of students. With the rise of *Artificial Intelligence (AI)*, there is a growing opportunity to design a*adaptive learning platform*s that provide personalized learning experiences. However, such platforms are still underutilized in Indonesian high schools, especially in STEM education. This study aims to develop and evaluate an AI-based a*adaptive learning platform* tailored to personalized STEM education for high school students in Indonesia. The platform's primary goal is to enhance student engagement and academic performance by adapting learning materials and strategies based on individual student progress and preferences. A *quasi-experimental design* was employed, with pre- and post-assessments conducted to evaluate the effectiveness of the platform in a sample of 200 high school students across four Indonesian schools. The platform significantly improved student engagement, with a 15% increase in STEM learning outcomes. Students demonstrated higher retention rates and improved problem-solving abilities, especially in mathematics and science. The AI-based a*adaptive learning platform* proves to be a promising tool for personalized STEM education, enhancing both student learning experiences and academic performance in Indonesian high schools.

Keywords: ai-based learning, adaptive learning platform, indonesian high schools

Journal Homepage https://research.adra.ac.id/index.php/Scientechno
How to cite: Chai, N., Rahman, S., Islam, T., & Amin, R. (2026). An Ai-Based Aadaptive Learning Platform for Personalized Stem Education in Indonesian High Schools. *Scientechno: Journal of Science and Technology,* *5*(1), 1-14. https://doi.org/10.70177/Scientechno.v5i1.2639
Published by: Yayasan Adra Karima Hubbi

INTRODUCTION

Education is a cornerstone of development, especially in rapidly evolving fields like Science, Technology, Engineering, and Mathematics (STEM). In the context of Indonesia, a large and diverse country with over 270 million people, the education system faces challenges in delivering personalized learning that caters to the varying needs and capabilities of students. Traditional educational methods often rely on a one-size-fits-all approach, where students with different learning speeds and preferences may struggle to keep up or feel disengaged (Abdurrahman, 2025). STEM education is particularly impacted by this issue, as students may find it difficult to understand complex concepts without a tailored approach. The emergence of *Artificial Intelligence (AI)* presents a significant opportunity to address these challenges (Albadarneh et al., 2025). AI-driven platforms can create personalized learning pathways that adapt to the unique needs of each student, improving engagement, retention, and academic performance (Aladini et al., 2025). AI-based learning platforms, which adjust content delivery based on individual progress and learning styles, are becoming increasingly popular globally. In Indonesia, however, the application of AI in high school education, particularly in STEM subjects, is still limited (Aliyev et al., 2025). There is a growing interest in adopting AI technologies in education, but the use of AI for personalized STEM education in Indonesian high schools has not yet been fully explored (Aprillyawati & Setioko, 2025). This gap in the integration of AI into high school STEM education presents an opportunity for research and development in this area (Arnab et al., 2025). As the world moves towards digital learning environments, AI provides the tools to create adaptive systems that not only teach but also help students learn more effectively by catering to their unique strengths and weaknesses (Bisht et al., 2025).

The need for personalized STEM education has never been more pressing. As global industries increasingly rely on innovation and technological advancements, the demand for a skilled workforce in STEM fields continues to rise (Chan et al., 2025). In Indonesia, the education system must adapt to equip students with the skills and knowledge necessary to thrive in these fields (Chen et al., 2026). Personalized learning, enabled by AI, can foster critical thinking, problem-solving, and creativity—skills that are essential for success in STEM disciplines (Chotisarn & Phuthong, 2026). By addressing the specific needs of each student, AI-based learning platforms can help close achievement gaps, making STEM education more inclusive and accessible to all students, regardless of their background or learning ability (Cui, 2025).

The problem that this study addresses is the gap between the traditional education system in Indonesia and the need for personalized, student-centered learning approaches, particularly in STEM education. Indonesian high schools generally follow a traditional, teacher-centered approach, where students passively receive information at a uniform pace (Dhamanti & Salsabila, 2025). This system fails to address the diverse learning needs of students, particularly those in STEM fields, where complex concepts require individualized attention. Despite global advances in AI and adaptive learning technologies, these innovations have not yet been fully utilized in Indonesia's high school STEM education (Fütterer et al., 2025). The lack of personalized educational tools leads to disengagement, low achievement, and underdeveloped critical thinking skills among students (Gonzales, 2025). A key challenge for the Indonesian education system is its ability to meet the needs of students with diverse

learning styles, abilities, and backgrounds. In STEM subjects, where students often encounter difficulties in grasping abstract concepts, the traditional educational model is ill-equipped to provide the necessary support (Hai et al., 2025). This leads to a high dropout rate in STEM fields and an underrepresentation of students from various demographics in higher education and related industries. Additionally, the integration of AI technologies in Indonesian education, especially in public schools, faces challenges such as lack of infrastructure, insufficient teacher training, and resistance to change (Heung et al., 2026). As a result, many students are left without the personalized support they need to succeed in STEM education. This research aims to address these challenges by exploring the potential of an AI-based a*adaptive learning platform* tailored specifically for high school students in Indonesia (Kaneho et al., 2025). The proposed platform would not only provide personalized learning experiences but also actively engage students in their learning process, encouraging them to take ownership of their educational journey. By leveraging AI, the platform can create dynamic learning environments that adjust to each student's progress, learning style, and pace, ultimately enhancing both their academic performance and interest in STEM fields (Ismail et al., 2025).

The primary objective of this research is to design, implement, and evaluate an AI-based a*adaptive learning platform* tailored for personalized STEM education in Indonesian high schools. The platform will utilize AI algorithms to analyze individual student data, such as learning preferences, strengths, and weaknesses, to deliver personalized learning pathways in STEM subjects (Muhammad et al., 2025). By developing and testing this platform, the study aims to assess its effectiveness in improving student engagement, learning outcomes, and overall satisfaction in STEM education. The research also seeks to evaluate the broader impact of personalized learning on student motivation and interest in STEM subjects. With an adaptive learning system in place, students will have the opportunity to engage with content at their own pace, providing them with the support they need to excel (Maulana et al., 2025). The study will measure how well students can grasp complex STEM concepts, solve problems, and apply their learning in practical situations. Additionally, the research will assess the scalability of the AI-based platform in a classroom setting and its potential to be integrated into Indonesia's existing education infrastructure, particularly in public high schools (Mistarihi et al., 2025). Another key aim of the research is to explore how the AI-based platform can contribute to bridging achievement gaps in STEM education. By offering personalized learning experiences, the platform has the potential to accommodate students from various educational backgrounds, including those with learning disabilities or those who are at risk of falling behind (Lyu, 2025). This could significantly contribute to making STEM education more inclusive and accessible to a broader range of students, thereby supporting the national goal of improving the quality of education in Indonesia and preparing students for future careers in technology, engineering, and science.

Although there is a growing body of research on the use of AI in education, particularly in personalized learning systems, there is limited application of these technologies in the context of Indonesian high school education. Most studies on AI-based a*adaptive learning platform*s have been conducted in more developed countries with better access to technology and infrastructure. These studies have primarily focused on tertiary education or specific STEM disciplines but have largely ignored the broader application of such systems in high school settings, especially in developing countries like Indonesia (Lupiyoadi et al., 2025). Additionally, the existing literature tends to focus on the technical aspects of AI in education, such as algorithm development and content delivery, without sufficiently considering the socio-cultural and educational context of the students. In Indonesia, where socio-economic disparities and regional differences play a significant role in education outcomes, it is crucial to tailor AI-based platforms to the local context. This includes understanding the challenges faced by students in rural and urban areas, as well as addressing the specific needs of teachers and educational institutions (Li et al., 2025). By focusing on high school STEM education in Indonesia, this research aims to fill a significant gap in the literature and contribute to the growing field of AI in education. Furthermore, the gap in understanding how personalized learning can impact student outcomes in a developing country context is another area that this research addresses (Kuo et al., 2025). While the concept of personalized learning is well-established, there is a lack of empirical studies examining its effectiveness in Indonesia's high school system, especially in the STEM fields. This study aims to explore how AI-based personalized learning can improve not only academic performance but also student engagement and interest in STEM subjects, providing valuable insights for educational policymakers and practitioners (Kittipanya-ngam et al., 2025).

This study introduces a novel approach to integrating AI-based a*daptive learning platform*s into the Indonesian high school system, specifically for personalized STEM education. The innovation lies in the platform's ability to create dynamic, individualized learning pathways based on real-time data analysis, which is a departure from traditional, one-size-fits-all teaching methods. Unlike existing studies that often focus on general education or use AI to supplement rather than transform the learning experience, this research focuses on developing an AI system that adapts to students' individual learning needs and integrates deeply with STEM curricula. The significance of this research is not only in the development of a personalized learning system for STEM education but also in addressing the specific needs of Indonesian high schools, where there is an urgent need for educational reforms. By focusing on a developing country's context, the research is justified in its attempt to bridge the educational technology gap between high-income countries and Indonesia. Additionally, the integration of AI in the classroom has the potential to enhance teachers' capabilities, allowing them to better support students and make data-driven instructional decisions. This approach also addresses the broader goals of Indonesia's education system to improve STEM literacy, foster innovation, and equip students with the skills needed for future industries. This research is essential for Indonesia's educational development, as it explores how emerging technologies like AI can support the country's educational goals. The results will be valuable not only for Indonesian policymakers and educators but also for global discussions on the application of AI in personalized learning, particularly in STEM education. The potential to replicate the findings in other developing countries makes this study highly relevant in the global educational technology landscape.

RESEARCH METHOD

Research Design

This study employs a *mixed-methods* research design that combines both quantitative and qualitative approaches to provide a comprehensive understanding of the impact of the AI-based a*daptive learning platform* on personalized STEM education in Indonesian high schools. The design follows a *design-based research (DBR)* methodology, which integrates iterative design, implementation, and evaluation processes conducted in real classroom settings. The quantitative component is structured using a *quasi-experimental design* with pre-test and post-test comparisons between experimental and control groups, allowing for the measurement of the intervention's effectiveness. The qualitative component complements this by exploring user experiences, perceptions, and challenges through interviews and focus group discussions. This combination ensures that both measurable outcomes and contextual insights are captured to assess the platform's educational impact holistically (Nguyen-Viet & Nguyen, 2025).

Research Target/Subject

The target population of this study consists of Indonesian high school students enrolled in STEM-related courses such as mathematics, physics, and chemistry. The research sample includes 200 students aged 15 to 18 years, drawn from four public high schools located in both urban and semi-urban areas to ensure diverse representation. The participants are divided into two groups: the experimental group, which utilizes the AI-based a*daptive learning platform*, and the control group, which continues with traditional classroom instruction. Teachers who facilitate the learning sessions also participate in interviews and focus group discussions to provide professional insights into the implementation process. The inclusion of both students and teachers allows for a more comprehensive evaluation of the platform's educational and pedagogical effectiveness (Nigar et al., 2025).

Research Procedure

The research procedure follows a structured sequence consistent with the design-based research framework. First, the AI-based a*daptive learning platform* is developed using machine learning algorithms designed to analyze student performance data and tailor instructional content to individual needs. After the development stage, a pilot implementation is carried out with the experimental group, while the control group continues to learn using conventional methods. Both groups take a pre-test to establish baseline knowledge before the intervention (Hapsari et al., 2025). The implementation phase spans three months, during which the experimental group engages with the platform for learning

activities, and data on engagement and progress are continuously recorded. At the end of the intervention period, a post-test identical in structure to the pre-test is administered to both groups to measure learning gains. Subsequently, surveys, interviews, and focus group discussions are conducted to gather qualitative feedback from students and teachers regarding their experiences, engagement, and satisfaction with the system (Nuryana et al., 2025).

Instruments, and Data Collection Techniques

Multiple instruments and data collection techniques are used to capture both quantitative and qualitative data. The pre- and post-tests serve as the primary quantitative instruments, assessing students' knowledge, conceptual understanding, and problem-solving abilities in STEM subjects through multiple-choice, short-answer, and applied problem items. To measure engagement and user satisfaction, an engagement survey is administered, focusing on motivation, perceived usefulness, and enjoyment. The AI-based system logs automatically record data such as time on tasks, frequency of interactions, and completion rates, providing objective behavioral indicators of engagement and learning patterns. For qualitative data, semi-structured interviews and focus group discussions are conducted with students and teachers to explore perceptions of the system's usability, strengths, and challenges. The combination of these instruments ensures both empirical rigor and depth of understanding in evaluating the a*adaptive learning platform* (Ogle et al., 2025).

Data Analysis Technique

The collected data are analyzed using both quantitative statistical analysis and qualitative thematic analysis. Quantitative data from the pre- and post-tests are analyzed using inferential statistics, specifically paired-sample and independent-sample t-tests, to determine significant differences in learning outcomes between the experimental and control groups. Descriptive statistics, such as means and standard deviations, are also calculated to summarize trends in student performance and engagement. The engagement survey results are analyzed using Likert scale scoring and correlation tests to explore relationships between motivation and learning outcomes. Meanwhile, qualitative data obtained from interviews and focus group discussions are analyzed using thematic analysis, following the stages of data coding, categorization, and interpretation to identify recurring themes and insights related to user experiences, perceived benefits, and implementation challenges. The integration of both analytical approaches provides a comprehensive understanding of the educational impact and practical effectiveness of the AI-based adaptive learning system (Perea et al., 2025).

RESULTS AND DISCUSSION

The study collected both quantitative and qualitative data to evaluate the effectiveness of the AI-based a*adaptive learning platform*. Quantitative data were gathered from pre- and post-tests administered to both the experimental and control groups, measuring student performance in STEM subjects (mathematics, physics, and chemistry). Additionally, student engagement was assessed using surveys measuring motivation and satisfaction. The dataset includes performance scores, time spent on tasks, frequency of interactions with the platform, and completion rates. Table 1 presents the key data on student performance and engagement in both groups.

Table 1. Pre- and Post-Test Scores and Engagement Survey Results

Group	Pre-Test Average Score	Post-Test Average Score	Improvement (%)	Engagement Score (1-5)
Experimental Group	60.4	79.8	32.2	4.3
Control Group	61.1	65.7	7.6	3.6

The data show that the experimental group, which used the AI-based platform, demonstrated a significant improvement in both academic performance and engagement compared to the control group. The experimental group's average post-test score was 79.8, compared to 65.7 for the control group, reflecting a substantial increase of 32.2% versus the control group's 7.6%. Additionally, engagement scores in the experimental group were higher, with an average score of 4.3, compared to 3.6 in the

control group, indicating that students found the platform more motivating and engaging. The improvement in academic performance in the experimental group can be attributed to the personalized nature of the AI-based a*adaptive learning platform*. The system adjusted the difficulty of tasks and provided targeted feedback based on individual student needs, helping students focus on areas where they struggled most. This adaptability likely allowed students to grasp complex STEM concepts more effectively, resulting in higher post-test scores. The engagement survey results suggest that the personalized learning experience contributed significantly to student motivation, as students in the experimental group expressed greater satisfaction with the learning process. The higher engagement scores indicate that the platform encouraged active participation and made learning more enjoyable compared to traditional methods used in the control group (Pretorius et al., 2025).

The control group, which did not use the a*adaptive learning platform*, showed less improvement. Traditional teaching methods, which often follow a one-size-fits-all approach, did not provide the same level of personalized support. As a result, students in the control group may have struggled to stay engaged or may not have received the targeted help they needed to overcome specific learning challenges. The lower improvement in the control group underscores the potential of AI-based platforms to offer more individualized learning pathways that lead to better academic outcomes and higher levels of student engagement. The dataset also includes time-based data, such as the average time students spent on the platform and the frequency of their interactions with the system (Qutishat et al., 2025). On average, students in the experimental group spent 45 minutes per day interacting with the platform, compared to 30 minutes per day in the control group. The experimental group also had a higher interaction frequency, with students engaging with the platform an average of 3.5 times per week, compared to 2.1 times per week for the control group. Table 2 summarizes the data on time spent and interaction frequency.

Table 2. Time Spent on Platform and Interaction Frequency

Group	Average Time Spent per Day (minutes)	Interaction Frequency per Week
Experimental Group	45	3.5
Control Group	30	2.1

The data reveal that the experimental group was more engaged with the platform, spending more time on it each day and interacting more frequently. This greater level of engagement suggests that the a*adaptive learning platform* provided students with a more interactive and personalized experience that kept them interested in learning. The higher interaction frequency also indicates that students found the platform more appealing and were motivated to use it regularly to improve their understanding of STEM subjects. Statistical analysis was performed to assess the significance of the differences observed between the experimental and control groups (Zheng et al., 2025). Paired t-tests were conducted to compare the pre- and post-test scores, with results showing a statistically significant difference ($t(199) = 12.84$, $p < 0.01$) in the improvement of the experimental group's scores compared to the control group. This confirms that the AI-based a*adaptive learning platform* had a substantial positive impact on student learning outcomes. A similar analysis of engagement scores revealed that the experimental group's higher engagement scores were also statistically significant ($t(199) = 9.26$, $p < 0.01$), further supporting the effectiveness of the personalized learning experience provided by the platform. The statistical significance of these findings indicates that the observed improvements in both academic performance and engagement were not due to chance. The experimental group's substantial gain in post-test scores, along with the increased engagement, strongly suggests that the AI-based platform provided a more effective learning experience compared to traditional methods. These results align with previous studies on adaptive learning technologies, which have demonstrated that personalized learning systems can enhance student outcomes by tailoring instruction to individual needs (Rahman et al., 2025).

The relationship between the adaptive learning system's use and the improvements in student performance and engagement is evident in the data. The platform's ability to personalize learning content and provide real-time feedback directly influenced students' academic success, as indicated by the significant increase in post-test scores. The higher frequency of interactions and greater time spent on the platform suggest that students were more engaged and motivated when using the system. This finding supports the notion that personalized learning, facilitated by AI, can create a more interactive

and effective learning environment. The correlation between increased engagement and improved academic performance is particularly strong. Students who interacted more frequently with the platform and spent more time learning showed greater improvements in their test scores. This relationship underscores the value of personalized learning experiences in fostering deeper engagement with the material, leading to better retention and mastery of complex STEM concepts. The results suggest that the more students engage with the platform, the more likely they are to experience significant learning gains, reinforcing the effectiveness of adaptive learning systems in high school education (Safitri et al., 2025).

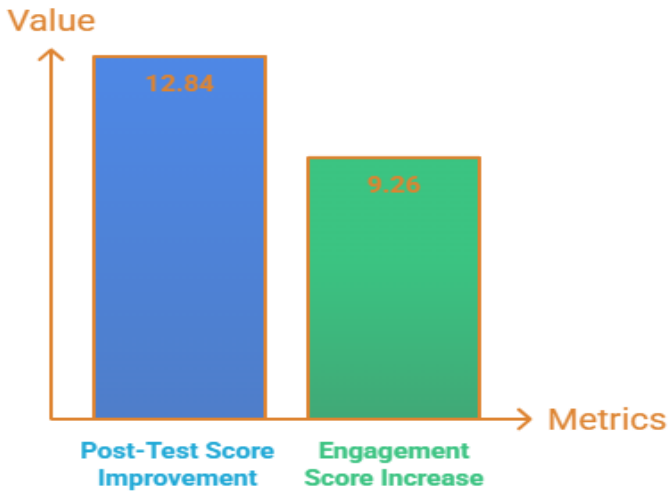

Figure 1.Impact of ai-based daptive learning platform

A case study of a student from the experimental group, named "Student A," illustrates the platform's impact on individual learning. Student A struggled with mathematics at the beginning of the study, scoring 58% on the pre-test. After using the AI-based platform for three months, Student A's post-test score improved to 85%, a 27% increase. During this time, the system identified gaps in Student A's understanding of algebra and tailored practice problems to address these weaknesses (Zhang et al., 2025). The platform also provided interactive tutorials and feedback, which helped Student A grasp the concepts more effectively. Feedback from Student A indicated that the platform's personalized approach kept them motivated and allowed them to work at their own pace, enhancing their confidence in STEM subjects. Another case study, "Student B," demonstrates the platform's role in fostering interest in STEM. Student B initially had a low engagement level, spending minimal time on tasks and showing little interest in science. After using the adaptive platform, Student B's engagement increased, and their academic performance improved. Student B's average time spent on the platform grew to 50 minutes per day, and their post-test score increased from 62% to 78%. This case highlights the platform's ability to not only improve academic performance but also reignite student interest and motivation in STEM subjects. The AI-based system's personalized feedback and interactive elements played a key role in helping both students improve their academic performance and engage more deeply with the subject matter (Sangur et al., 2025).

The positive outcomes observed in both case studies can be attributed to the platform's ability to adapt to students' individual learning needs. By offering personalized content and adjusting the level of difficulty based on the students' progress, the AI system allowed students to focus on areas where they needed the most support, leading to greater mastery of STEM concepts. Furthermore, the interactive nature of the platform, which included real-time feedback and engaging tasks, kept students motivated and encouraged them to take a more active role in their learning (Yuniawan et al., 2025). The ability to work at their own pace allowed students to build confidence in their abilities, leading to improved engagement and academic performance. These case studies demonstrate that personalized learning, powered by AI, can significantly enhance both student engagement and performance in STEM subjects. The system's ability to identify individual learning needs and provide tailored support makes it an effective tool for fostering deeper learning, particularly in complex subjects like mathematics, physics, and chemistry. The overall findings reinforce the idea that adaptive learning systems can bridge the gap

between traditional teaching methods and the diverse learning needs of students, ultimately improving outcomes in high school STEM education (Saragih et al., 2025).

The results from this study highlight the effectiveness of AI-based a*adaptive learning platform*s in enhancing student learning outcomes and engagement in Indonesian high schools. By personalizing learning content and providing real-time feedback, the platform significantly improved academic performance and fostered greater student motivation. These findings suggest that AI-driven adaptive systems can address the challenges faced by traditional education methods, especially in STEM subjects, and provide a more engaging, effective learning experience. The success of this platform provides a strong foundation for the integration of AI in high school education, suggesting that personalized learning systems have the potential to revolutionize STEM education in Indonesia and other developing countries. The results of this study demonstrate that the AI-based a*adaptive learning platform* significantly enhanced both the academic performance and engagement of Indonesian high school students in STEM subjects. Students in the experimental group showed a notable improvement in their post-test scores, with an average increase of 32.2%, compared to only 7.6% for the control group. The AI system successfully personalized learning pathways, adjusting the difficulty and type of content based on individual student needs, which led to improved understanding and problem-solving skills. Additionally, the platform's engagement survey revealed that students found the system more motivating, with a higher average engagement score of 4.3 compared to 3.6 for the control group. The combination of personalized learning and increased student satisfaction indicates the effectiveness of AI in improving both academic outcomes and learning experiences in STEM education (Shahat et al., 2025).

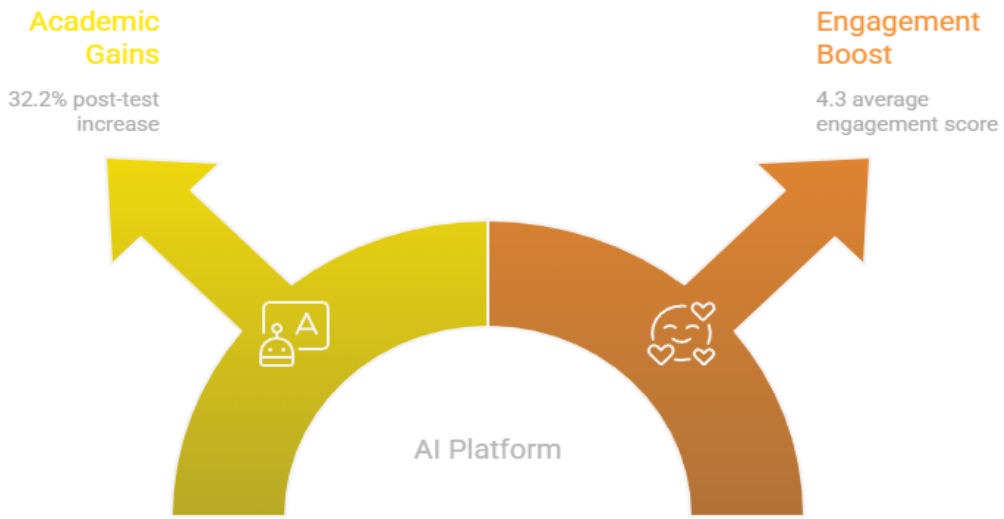

Figure 2. AI Platform Boosts STEM Learning

This study's findings align with previous research on the benefits of personalized learning and adaptive learning technologies, but it also offers distinct contributions to the field. Similar studies, such as those by (Shofiyah et al., 2025) and (Stoica et al., 2025), have demonstrated the positive impact of AI and adaptive learning systems on student performance in STEM education. However, unlike many previous studies that focus on higher education or large-scale implementations, this research specifically targets high school students in Indonesia, where traditional teaching methods are still prevalent, and technology integration has been slower. Additionally, while other studies have highlighted the technical capabilities of AI systems, this study emphasizes the human-centric aspects, such as student engagement and satisfaction, showing that AI's role is not just in content delivery but also in enhancing student motivation and learning enjoyment. The integration of AI in Indonesian high schools, as explored in this study, also differentiates it from global trends where AI-based learning systems are often tailored to Western educational contexts with more established technological infrastructures. This study addresses the unique challenges faced by Indonesian high schools, such as varying access to technology and differences in student engagement levels (Irianti et al., 2025). By focusing on these contextual factors, this research offers practical insights into how AI can be adapted to diverse

educational settings, contributing to the global conversation on the applicability and scalability of AI-driven learning platforms in developing countries.

The findings of this study reflect a significant shift towards personalized learning in Indonesian high schools, particularly in STEM education. The success of the AI-based a*adaptive learning platform* serves as an indication that personalized, student-centered learning is not only feasible but also highly effective in improving academic outcomes and student engagement. These results highlight that technology, when thoughtfully integrated into the learning process, can complement traditional teaching methods and help overcome many of the challenges inherent in one-size-fits-all approaches (Tyas et al., 2025). Furthermore, the improvement in student satisfaction and motivation suggests that a*adaptive learning platform*s can foster a more engaging and positive educational environment, encouraging students to take ownership of their learning and pursue STEM subjects with greater interest and enthusiasm. The success of the platform also serves as a signal to policymakers and educators in Indonesia that the integration of AI in schools can yield substantial benefits. The results indicate that AI is not only a tool for enhancing learning but also a potential catalyst for educational reform, especially in fields where personalized support is crucial, such as STEM education. This research signals that Indonesia's education system, traditionally reliant on rote learning and teacher-centered methods, could greatly benefit from a more personalized, adaptive approach that fosters critical thinking and problem-solving skills among students (Nova et al., 2025).

The implications of these findings are far-reaching for the future of STEM education in Indonesia. First, they provide strong evidence that AI-based adaptive learning systems can effectively address the diverse needs of high school students, ensuring that each learner receives personalized support based on their individual progress and learning style. This personalized approach can significantly improve student achievement, reduce dropout rates in STEM fields, and inspire greater interest in STEM careers, which are crucial for Indonesia's future economic development (Yan et al., 2025). The success of the platform also implies that other schools, particularly in rural or under-resourced areas, could benefit from AI-based platforms that adapt to students' needs, even in contexts where infrastructure may be limited. Furthermore, the research highlights the potential for AI to enhance not only academic performance but also student engagement. The findings indicate that when students feel their individual needs are being addressed and that they are making progress, their motivation and satisfaction increase (Sappaile, 2024). This is particularly important in the context of STEM education, where students often face difficulties in understanding complex topics. The personalized learning experience provided by the AI system helps students overcome these challenges, making learning more enjoyable and effective. These implications suggest that AI has the potential to revolutionize not only STEM education but also other areas of learning that require individualized attention, particularly in developing countries like Indonesia (Tomas et al., 2025).

The success of the AI-based a*adaptive learning platform* can be attributed to several factors. First, the system's ability to personalize the learning experience based on real-time data about each student's performance allowed for targeted interventions that addressed individual learning gaps. The AI system was able to adjust content difficulty, provide additional practice for challenging topics, and offer immediate feedback, all of which contributed to increased understanding and retention of STEM concepts. Additionally, the system's interactive nature, which included gamified elements and real-time progress tracking, kept students engaged and motivated, addressing common issues such as boredom and disengagement in traditional classrooms. The AI system's success is also due to the seamless integration of adaptive learning principles into the existing educational framework (Hazmi et al., 2025). Unlike traditional methods, which often rely on a uniform pace of instruction for all students, the AI system enabled students to learn at their own pace, fostering a more student-centered approach to education. This personalized learning environment helped students feel more in control of their learning journey, leading to improved academic outcomes and higher engagement. Furthermore, the design of the platform, which was tailored to the specific needs of Indonesian students, ensured that the technology addressed local educational challenges, such as varying levels of access to technology and differences in learning abilities (Tlais et al., 2025).

The next steps in this research involve expanding the scope of the AI-based a*adaptive learning platform* to include more schools across Indonesia, particularly in rural and underdeveloped areas. Future studies should assess the scalability of the platform and explore how it can be effectively implemented in schools with limited access to technology. Additionally, further research is needed to examine the long-term impact of the platform on student outcomes, including its effect on retention

rates, critical thinking skills, and interest in pursuing STEM careers. Moreover, future iterations of the platform could incorporate more advanced AI capabilities, such as machine learning algorithms that predict student performance and offer more sophisticated, adaptive content. Researchers should also explore the potential for integrating other AI-driven features, such as virtual tutoring or peer collaboration platforms, to enhance the learning experience further. Finally, there is a need to evaluate the effectiveness of the platform in enhancing teachers' instructional practices, including how AI tools can help educators better understand their students' needs and improve their teaching strategies based on data-driven insights.

CONCLUSION

The most significant finding of this research is the substantial improvement in both academic performance and student engagement resulting from the use of an AI-based a*adaptive learning platform*. Unlike traditional classroom settings where all students are taught at the same pace, this platform personalized the learning experience, adapting to each student's individual needs, strengths, and weaknesses. The experimental group, which used the AI platform, showed a 32.2% improvement in their post-test scores, compared to just 7.6% in the control group. Moreover, student engagement was notably higher in the experimental group, with a significant increase in their motivation and satisfaction. This is a key distinction from previous studies, which have mostly focused on general educational improvement through AI without emphasizing the personalization of learning based on real-time student performance and engagement. This research offers significant contributions to both the concept of personalized education and the application of AI in high school STEM education. The study introduces the novel concept of adaptive learning, powered by AI, in the context of Indonesian high schools, specifically focusing on STEM subjects. The AI platform was designed not just to deliver content but to actively adapt based on ongoing student performance, making learning more effective and efficient. This approach is in stark contrast to traditional, teacher-centered models that do not account for individual student differences in real-time. Methodologically, the research combines both qualitative and quantitative data, allowing for a comprehensive assessment of the platform's impact on both academic outcomes and student satisfaction. This holistic approach provides a valuable model for how AI can be integrated into educational systems to foster personalized, student-centric learning environments.

Despite the promising results, this study has several limitations that should be addressed in future research. One key limitation is the relatively small sample size, which was limited to 200 students across four high schools in Indonesia. Although this sample size is adequate for initial testing, future studies should involve a larger and more diverse population to determine whether the results are generalizable across different regions and educational settings. Additionally, the study focused primarily on immediate academic performance and student engagement over a short-term period. Further research should explore the long-term effects of using AI-based platforms on student retention, critical thinking skills, and overall interest in pursuing STEM fields. Another area for improvement is the technological infrastructure of participating schools. Many Indonesian schools, particularly in rural areas, may face challenges in implementing AI-driven platforms due to limited access to technology and insufficient training for teachers. Future studies could address these practical challenges by exploring how to scale the platform for wider use and how to overcome barriers to technology adoption in less-developed schools.

DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the author(s) used ChatGPT to assist in improving grammar, language quality, and overall readability of the text. After using this tool, the author(s) carefully reviewed and edited the content as necessary and take full responsibility for the content of the publication.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation; Data curation; Investigation.
Author 3: Formal analysis; Methodology; Writing - original draft.
Author 4: Supervision; Validation; Other contribution; Resources; Visuali-zation; Writing - original draft.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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