

Optimizing Learning: Adaptive Technology Integration in Indonesia's Education System

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Abstract

Adaptive technology in education offers an innovative solution to enhance learning quality by personalizing instructional materials according to students' needs. This study aims to analyze the potential of adaptive technology in Indonesia's education system and identify its implementation challenges. Using a literature review method, this research examines various studies on the application of adaptive technology in education, particularly within the "Merdeka Belajar" framework. The findings indicate that adaptive technology can enhance student engagement, facilitate data-driven learning, and assist teachers in accurately identifying student difficulties. However, major challenges in its implementation include limited infrastructure, gaps in digital literacy among educators, and cultural resistance to technology in education. To address these barriers, strategic measures such as strengthening digital infrastructure, implementing TPACK-based teacher training, and educating communities about the benefits of adaptive technology are necessary. With these recommendations, adaptive technology is expected to be effectively integrated into Indonesia's education system, fostering more inclusive, flexible, and high-quality learning.

Keywords: Adaptive technology, optimizing learning, Indonesian education.

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INTRODUCTION

Modern education faces great challenges in creating relevant, inclusive, and adaptive teaching and learning processes to meet the diverse needs of students. Adaptive technology in education is emerging as an innovative solution that allows personalization of learning according to student's individual abilities, needs, and preferences. This technology utilizes intelligent algorithms to adjust teaching materials, teaching methods, and learning speed in real-time, thereby creating a more effective and personalized learning experience (Capuano & Caballé, 2020; Jing et al., 2023; Nazmi et al., 2023). Research shows that the integration of adaptive technology can increase student engagement in the learning process as well as help students better understand the material through learning analytics-

based feedback (Maryani et al., 2023; Molenaar & van Campen, 2016; Peng et al., 2019).

In the Indonesian context, adaptive technology is very relevant to the concept of "Freedom of Learning," which emphasizes the freedom of students to learn according to their respective learning styles. This concept supports a flexible and responsive curriculum to student needs, as well as encouraging the integration of technology to improve the quality of education (Dito & Pujiastuti, 2021; Mustaghfiroh, 2020). In addition to providing benefits to students, adaptive technology also helps educators by providing ongoing professional training, access to digital resources, and data-driven platforms to monitor student progress (Maryani et al., 2023; Putri et al., 2023). Thus, adaptive technology offers great potential in creating an inclusive, relevant, and high-quality learning environment in Indonesia (Wantini et al., 2022).

However, research addressing the application of adaptive technology in Indonesia is still very limited, especially in relation to local challenges such as inadequate infrastructure, technology skills gap among educators, and cultural differences that affect technology acceptance (Ghavifekr & Rosdy, 2015; Rahiem, 2020). For this reason, solutions are needed in the form of intensive training for educators, educational policy support, and increased access to technology infrastructure to encourage effective implementation.

The integration of adaptive technology is expected to make a real contribution to improving student learning outcomes and supporting educators in creating a more efficient learning process (Alfiyanto et al., 2024). For example, the use of the Ruangguru platform in Indonesia has shown success in creating flexible and interactive learning, which provides students with a better learning experience (Fitria, 2024). This contribution is very important to encourage the transformation of Indonesia's education system in a more adaptive and sustainable direction.

Although the potential of adaptive technology is huge, its application in Indonesia faces a number of significant obstacles. One of the main obstacles is the lack of technology skills among teachers, who often feel unprepared or do not have enough knowledge to integrate adaptive technology into learning (Tosuntaş et al., 2019; Windiarti et al., 2023). This obstacle is further exacerbated by the limited professional training designed to support teachers in using technology effectively. In addition, infrastructure limitations such as uneven internet access, especially in rural areas, are a major challenge in creating an education system based on adaptive technology (Subroto et al., 2023).

Another challenge is cultural resistance to technology. Many parents and the public are skeptical of the use of technology in education, often seeing it as a substitute for the role of teachers rather than as a support tool (Gusteti et al., 2024; Rahiem, 2020). This shows the importance of an educational approach that involves parents and the community in supporting the application of adaptive technology.

The solution to this problem includes intensive training for teachers through the TPACK (Technological, Pedagogical, and Content Knowledge) framework that allows teachers to integrate technology, pedagogy, and learning content effectively (Aulia et al., 2023). In addition, education policies that support the development of technological infrastructure throughout Indonesia are also very necessary (Chen et al., 2022). Practically, this approach can increase student engagement in learning,

while theoretically, this solution enriches the literature on educational technology adaptation in developing countries.

Adaptive technology in education is based on the theory of constructivism, which emphasizes that learning is an active process in which students build knowledge through interaction with their environment. Adaptive technology supports this principle by providing personalized teaching materials based on students' needs and learning styles, thereby creating a more relevant and contextual learning experience (Jazuly et al., 2022). In addition, this approach is aligned with the theory of self-regulated learning-based learning, which motivates students to take control of their learning process through real-time feedback and adjustments (Hamer & Lely, 2020; Peng et al., 2019).

The advantage of constructivism theory lies in its ability to accommodate individual differences among students, fostering an inclusive and responsive learning experience. In theory, the integration of adaptive technology within this framework enhances the development of technology-based learning models, offering fresh insights into how technology can optimize student learning outcomes. However, despite the growing body of research on adaptive learning, a significant research gap remains regarding its application in culturally diverse and infrastructure-challenged environments, such as Indonesia. Previous studies have predominantly focused on technologically advanced settings, overlooking the complexities of local contexts where socio-cultural diversity and digital infrastructure disparities play a crucial role in shaping learning experiences.

To bridge this gap, this study explores the integration of constructivist theory and adaptive learning technology within Indonesia's unique educational landscape. By addressing the intersection of pedagogy and technology in a region characterized by cultural heterogeneity and varying levels of technological access, this research offers a novel perspective on how adaptive learning can be effectively tailored to diverse educational settings.

This study aims to analyze the potential of adaptive technology in improving the quality of education in Indonesia, identify the key factors influencing its successful implementation, and provide strategic recommendations for optimizing its adoption. The uniqueness of this research lies in its focus on how adaptive learning can be contextualized within Indonesia's socio-cultural realities and infrastructure limitations, contributing new knowledge to the global discourse on educational technology.

By enriching the literature on the localized application of adaptive technology, this study provides valuable insights into the intersection of technology, pedagogy, and cultural adaptation. Furthermore, the findings offer practical guidance for policymakers and educators in designing strategies for successful adaptive technology implementation, particularly in teacher training and equitable technology infrastructure development.

RESEARCH METHOD

This study uses the literature review method to comprehensively analyze previous studies related to the application of adaptive technology in education, especially in the context of the education system in Indonesia. This study aims to explore the potential of adaptive technology in creating relevant, inclusive, and personalized

learning according to student needs, as well as identify the challenges faced in its implementation. The literature analyzed includes journal articles, books, research reports, and relevant educational policies, published within the last 10 years (2013–2023). These sources were obtained through searches in academic databases such as Scopus and Google Scholar using keywords such as adaptive learning technology, Indonesia education system, and Merdeka Belajar. The analysis was carried out thematically to identify key patterns in the literature, including potential, local challenges such as infrastructure and teacher skills, as well as strategic recommendations for effective implementation (Capuano & Caballé, 2020; Rahiem, 2020).

The results of the analysis revealed three main themes: the potential of adaptive technology in supporting personalized learning, implementation barriers in Indonesia such as the technology access gap and cultural resistance, and strategies that can be adopted to optimize its use. This study finds that adaptive technology is relevant to the concept of Freedom of Learning, which emphasizes curriculum flexibility and freedom of learning according to student needs. In addition, this study also provides evidence-based recommendations, such as the importance of teacher training through the TPACK framework and strengthening policies for the development of technological infrastructure in remote areas. By providing an in-depth overview of local opportunities and challenges, this study not only enriches the global literature on adaptive technologies, but also offers strategic guidance for educators and policymakers in integrating these technologies into Indonesia's education system in a sustainable manner (Jing et al., 2023; Maryani et al., 2023).

RESULTS AND DISCUSSION

Results

The Potential of Adaptive Technology in Improving Learning Outcomes

Adaptive technology has enormous potential in improving student learning outcomes in Indonesia. With its ability to personalize learning materials according to individual abilities and needs, this technology can create a more relevant and effective learning experience. Research shows that students who engage in personalized learning tend to be more motivated and have a better understanding of the material being taught (Hamer & Lely, 2020; Peng et al., 2019). In the context of education in Indonesia, the application of adaptive technology is in line with the principle of Freedom of Learning, which emphasizes the importance of students' freedom to learn according to their interests and potential (Dito & Pujiastuti, 2021; Mustaghfiroh, 2020).

Case studies conducted on learning platforms such as Ruangguru show that students who use adaptive technology can more easily understand difficult concepts. This is due to the presence of real-time feedback provided to students, which allows them to immediately recognize mistakes and correct them (Fitria, 2024). In addition, this technology also helps teachers in identifying difficulties faced by students, so that the interventions provided can be more targeted (Maryani et al., 2023). Thus, adaptive technology not only improves student learning outcomes, but also the efficiency of the overall learning process.

Furthermore, adaptive technology supports the development of students' critical and creative thinking skills. By giving students more control over their

learning process, this technology encourages them to explore different learning strategies and find the most effective way for them. This is in line with the broader goal of education, which is to prepare students to face challenges in an ever-changing world (Peng et al., 2019). Therefore, the integration of adaptive technology in the Indonesian education system can be an important step to improve the quality of education and student learning outcomes.

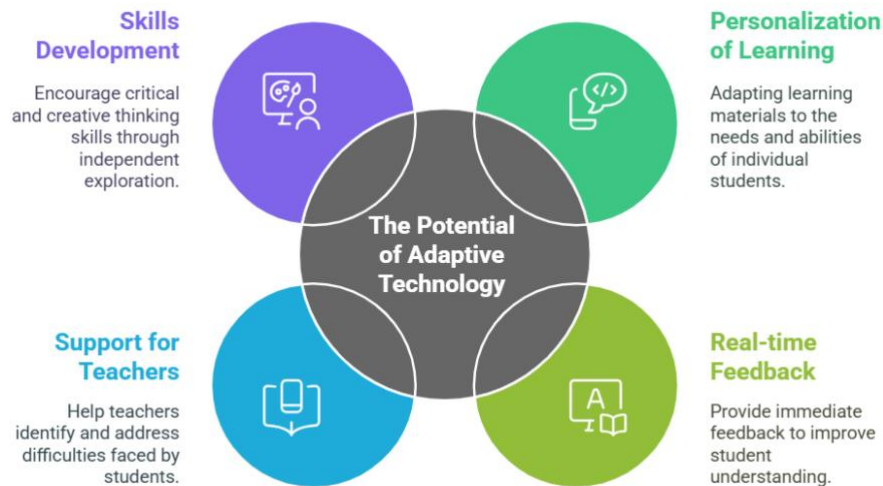


Figure 1. Improving Learning Outcomes with Innovative Adaptive Technologies

The image illustrates the concept of "Improving Learning Outcomes with Innovative Adaptive Technologies," centered around the "Potential of Adaptive Technology." It highlights five interconnected elements 1) Skills development, which emphasizes fostering critical and creative thinking through independent exploration; 2) Personalization of learning, focusing on adapting educational materials to meet the individual needs and abilities of students; 3) Real-time feedback, providing immediate responses to enhance student understanding; and 4) Support for teachers, assisting educators in identifying and addressing the challenges faced by their students. Overall, the image effectively conveys how adaptive technology can significantly enhance learning outcomes through an integrated and innovative approach.

Challenges of Adaptive Technology Implementation in Indonesia

Although adaptive technology offers many benefits, its implementation in Indonesia is not without challenges. One of the main obstacles is inadequate infrastructure, especially in rural areas. Limited internet access and lack of technological devices are significant problems that hinder the widespread adoption of this technology (Chen et al., 2022; Subroto et al., 2023). Without adequate infrastructure, many students and teachers are unable to harness the full potential of adaptive technology, ultimately reducing the effectiveness of learning.

In addition, there is a gap in technological skills among educators. Many teachers feel unprepared to integrate adaptive technology into their learning, due to a lack of professional training and mentoring (Tosuntaş et al., 2019; Windiarti et

al., 2023). This creates a situation where even though technology is available, its use is not optimal because teachers do not have the necessary knowledge or skills to utilize it effectively. Therefore, it is important to provide adequate training for teachers so that they can integrate adaptive technology into their learning practices.

The aspect of cultural resistance is also a significant challenge. Some people still see technology as a threat to the role of teachers, not as a tool that can support the learning process (Gusteti et al., 2024; Rahiem, 2020). To overcome these challenges, a holistic approach is needed that involves infrastructure updates, educator skill development, and public education about the benefits of technology in education. By involving all stakeholders, the application of adaptive technology can be carried out more effectively and sustainably.

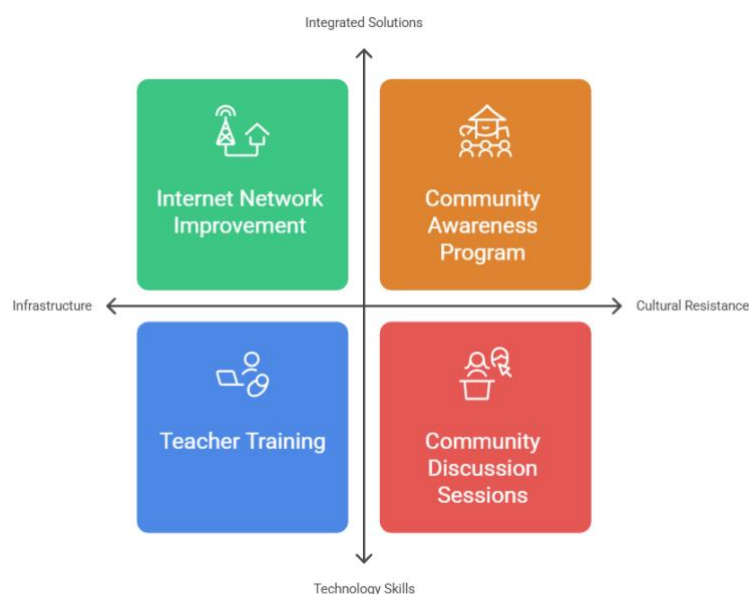


Figure 2. Overcoming Challenges in Adaptive Technology Implementation

The image presents a framework for "Overcoming Challenges in Adaptive Technology Implementation," organized into four quadrants that address key areas of focus: 1) Emphasizes internet network improvement, highlighting the necessity of robust infrastructure to support adaptive technologies; 2) Community awareness program, aimed at fostering understanding and acceptance of these technologies within the community, thereby reducing cultural resistance; 3) Teacher training, which is essential for equipping educators with the necessary skills to effectively utilize adaptive technologies; and 4) Community discussion sessions, promoting dialogue and collaboration among stakeholders to enhance technology skills. This comprehensive approach underscores the importance of integrated solutions in addressing the multifaceted challenges of implementing adaptive technology in educational settings.

The Relevance of Adaptive Technology to Freedom of Learning

Adaptive technology is very relevant to the principles carried out by Merdeka Belajar, which emphasizes flexibility and diversity in learning. With this technology, students can learn according to their style and needs, which supports

the diversity of individuals in the classroom (Dito & Pujiastuti, 2021; Mustaghfiroh, 2020). Research shows that adaptive technology-based platforms provide wider access to quality teaching materials, including for students in remote areas (Putri et al., 2023). It is crucial to ensure that all students, regardless of geographical location, have the same opportunity to get a quality education.

In addition, adaptive technology makes it easier for teachers to design teaching that is in accordance with the level of student competence. Through the learning analytics provided by this technology, teachers can obtain real-time student development data, which allows them to adjust the teaching methods and materials used (Capuano & Caballé, 2020; Jing et al., 2023). Thus, the integration of adaptive technology not only supports the achievement of the goal of Freedom of Learning, but also improves the quality of teaching provided by teachers.

Furthermore, the relevance of adaptive technology to Freedom of Learning is also seen in its ability to support inclusive and student-centered learning. By giving students more control over their learning process, this technology encourages them to become more active and engaged in learning. This is in line with Merdeka Belajar's goal to create a more democratic and participatory learning environment, where every student has a voice and a role in their learning process.

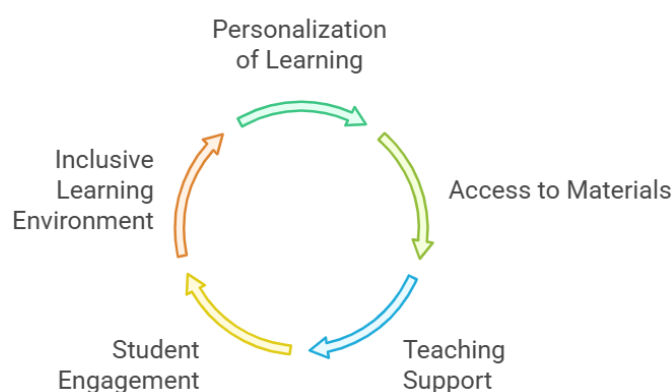


Figure 3. Adaptive Technology Cycle in Independent Learning

The image illustrates the "Adaptive Technology Cycle in Independent Learning," depicting a continuous loop that emphasizes the interconnected components essential for effective learning. At the center of the cycle is Personalization of Learning, which tailors educational experiences to meet individual student needs. This personalization is supported by Access to Materials, ensuring that learners have the resources they require. The cycle further includes Teaching Support, which provides educators with the tools and strategies necessary to facilitate learning. Student Engagement is highlighted as a critical element, fostering active participation and motivation among learners. Finally, the cycle emphasizes the importance of an Inclusive Learning Environment, creating a space where all students can thrive. This cyclical model underscores the dynamic relationship between these components, illustrating how adaptive technology can enhance independent learning experiences.

Strategies to Overcome Barriers to Adaptive Technology Implementation

To overcome the barriers that have been identified in the implementation of adaptive technologies, this study suggests several key strategies. First, training based on the TPACK (Technological, Pedagogical, and Content Knowledge) framework can be an effective solution. By providing training to teachers on how to effectively integrate technology, pedagogy, and content, they will be better prepared to use adaptive technology in learning (Aulia et al., 2023; Wantini et al., 2022). This training should include the use of adaptive platforms, student data management, and technology-based learning design.

Second, the development of technological infrastructure is also very important. The government needs to accelerate the development of digital infrastructure, especially in remote areas, by providing adequate internet access and affordable technological devices. Subsidies for devices such as laptops or tablets can be a solution to reduce the technology access gap (I-Ju Chen, 2020; Subroto et al., 2023). With better infrastructure, more students and teachers will be able to take advantage of adaptive technology in the learning process.

Third, education and community involvement are also important aspects in increasing the acceptance of adaptive technology. The public needs to be given an understanding of the benefits of technology in education through workshops or educational programs involving parents, teachers, and students. By increasing community awareness and support for educational technology, cultural resistance can be minimized, so that the application of adaptive technology can be carried out more smoothly (Gusteti et al., 2024; Rahiem, 2020).

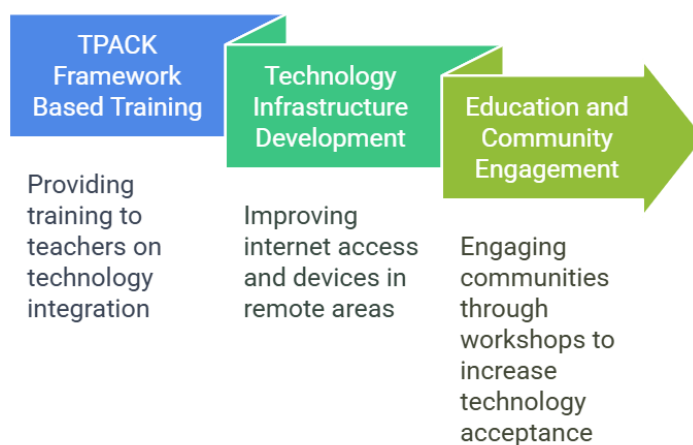


Figure 4. Strategies to Overcome Barriers to Adaptive Technology Implementation

The image outlines "Strategies to Overcome Barriers to Adaptive Technology Implementation," presenting a structured approach to addressing challenges in this area. The first strategy, TPACK Framework Based Training, focuses on providing educators with training on effectively integrating technology into their teaching practices. The second strategy, Technology Infrastructure Development, emphasizes the need to improve internet access and provide devices in remote areas, ensuring that all students have the necessary tools for learning. Lastly, Education and Community Engagement highlights the importance of involving communities

through workshops aimed at increasing acceptance of technology. Together, these strategies form a comprehensive plan to facilitate the successful implementation of adaptive technology in educational settings, ultimately enhancing learning outcomes for all students.

Theoretical Contribution: Integration of Technology and Constructivist Approach

The results of this study strengthen the relevance of constructivism theory in the context of technology-based learning. Adaptive technology supports students to build their knowledge through interaction with personalized teaching materials. This approach creates a more contextual and meaningful learning experience, which is in line with the principles of constructivism (Jazuly et al., 2022). By providing students with the opportunity to explore and interact with the material, adaptive technology helps them build a deeper and more comprehensive understanding.

In addition, adaptive technology also supports self-regulated learning-based learning. By providing students with the opportunity to set their own learning strategies, set goals, and receive real-time feedback, this technology encourages students to become more independent and responsible for their learning process (Hamer & Lely, 2020; Peng et al., 2019). This shows that the integration of technology not only strengthens existing learning theories, but also expands its application to the context of modern digital-based education.

Thus, the theoretical contribution of this study shows that the integration of adaptive technology in education is not only relevant in practice but also supports the development of existing learning theories. This opens up opportunities for further research on how technology can be used to improve learning experiences and educational outcomes in a variety of contexts.

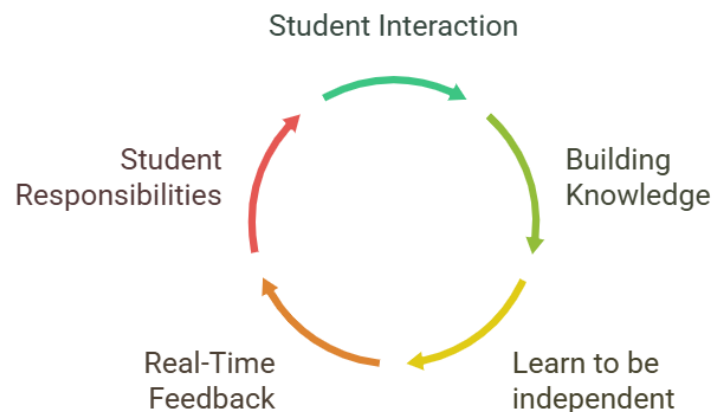


Figure 5. Technology-Based Constructivist Learning Cycle

The image depicts the "Technology-Based Constructivist Learning Cycle," illustrating a dynamic process that emphasizes active student engagement in the learning experience. At the center of the cycle is Student Interaction, which fosters collaboration and communication among learners. This interaction is supported by Student Responsibilities, encouraging learners to take ownership of their

educational journey. The cycle also includes Real-Time Feedback, providing immediate insights that help students understand their progress and areas for improvement. As students engage with the material, they work on Building Knowledge, constructing their understanding through exploration and inquiry. Finally, the cycle promotes the goal of Learning to be Independent, equipping students with the skills necessary to navigate their learning autonomously. This holistic approach underscores the importance of technology in facilitating a constructivist learning environment that empowers students.

Recommendations for Sustainable Implementation

To ensure the successful implementation of adaptive technology in Indonesia's education system, collaboration between various stakeholders is essential. Governments, educators, communities, and the private sector must work together to create a supportive education ecosystem. This study recommends several strategic steps for sustainable implementation.

First, increased investment in digital infrastructure is urgently needed, especially in hard-to-reach areas. The government should prioritize the development of internet networks and the provision of affordable technology devices to ensure all students have equal access to educational technology. Second, strengthening education policies is also key. The integration of adaptive technology into the national curriculum and the provision of budgets for educator training should be a priority. With supportive policies, the application of adaptive technology can be carried out in a more systematic and planned manner.

Third, continuous evaluation of the effectiveness of adaptive technology is also important. The use of evidence-based data to improve the design and implementation of future technologies will help ensure that the technologies used truly meet the needs of students and teachers (Chen et al., 2022; Wantini et al., 2022). With these steps, it is hoped that adaptive technology can be effectively integrated in the Indonesian education system, thereby improving the quality of education and overall student learning outcomes.

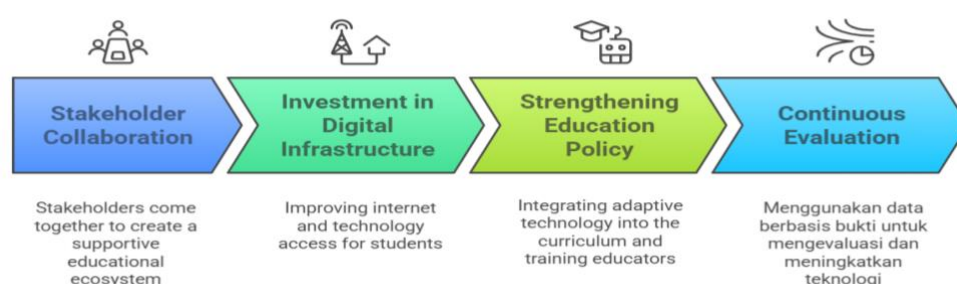


Figure 6. Sustainable Implementation of Adaptive Technology in Education

The image depicts the "Technology-Based Constructivist Learning Cycle," illustrating a dynamic process that emphasizes active student engagement in the learning experience. At the center of the cycle is Student Interaction, which fosters collaboration and communication among learners. This interaction is supported by Student Responsibilities, encouraging learners to take ownership of their educational journey. The cycle also includes Real-Time Feedback, providing

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Discussion

This study confirms and expands on previous findings regarding the potential of adaptive technology in enhancing student learning outcomes. Prior research has demonstrated that adaptive learning platforms facilitate personalized education, leading to increased motivation and comprehension among students (Hamer & Lely, 2020; Lu, 2019). Our findings align with these studies, highlighting that adaptive technology, when implemented effectively, enables students to grasp difficult concepts more easily due to real-time feedback and tailored instruction (Fitria, 2024). This indicates that the application of adaptive technology can be a valuable tool in improving students' learning experiences.

However, our research also reveals additional insights specific to the Indonesian educational landscape. Unlike previous studies conducted in technologically advanced environments, this study sheds light on the challenges faced by Indonesian educators and students, particularly regarding infrastructure limitations, digital literacy gaps, and cultural resistance (Chen et al., 2022; Subroto et al., 2023). These findings contrast with research from developed nations, where adaptive learning systems are more seamlessly integrated due to well-established technological infrastructures and educator readiness (Tosuntaş et al., 2019). This highlights the need for a more contextual approach in implementing adaptive technology in developing countries.

Several limitations of this study should be acknowledged. First, in terms of participant selection, this study focused primarily on students and teachers using adaptive technology platforms in select regions of Indonesia. Future research could expand to a broader sample that includes diverse educational institutions, including rural and underprivileged schools, to provide a more comprehensive analysis. Second, regarding the variables measured, this study primarily examined learning outcomes and engagement levels. While these are crucial indicators of educational success, additional variables such as long-term retention, cognitive load, and emotional responses to adaptive learning should be explored in future studies.

The findings of this study have implications beyond the specific sample and context examined. While the results are particularly relevant to the Indonesian education system, the identified challenges and benefits of adaptive technology implementation resonate with other developing countries facing similar infrastructural and pedagogical constraints (Gusteti et al., 2024). However, caution must be exercised in directly applying these findings to different educational settings without considering contextual factors. The effectiveness of adaptive technology is influenced by variables such as government support, digital literacy levels, and cultural perceptions of technology in education.

The results of this study hold significant implications for various stakeholders, including educators, policymakers, and technology developers. For educators, it is

essential that teachers receive adequate training to effectively integrate adaptive technology into their pedagogy. This study underscores the need for professional development programs that enhance teachers' digital competencies, aligning with the TPACK (Technological, Pedagogical, and Content Knowledge) framework (Aulia et al., 2023; Wantini et al., 2022). For policymakers, governments must prioritize digital infrastructure development, particularly in underserved regions, to ensure equitable access to adaptive learning tools. Lastly, technology developers should design adaptive learning platforms with user-friendly interfaces and localized content, collaborating with educators to tailor technology to students' needs.

CONCLUSION

This research emphasizes that adaptive technology has an important role in improving the quality of education in Indonesia. With its ability to adjust learning materials in real-time, this technology supports personalized learning in line with the principle of "Freedom of Learning." The results show that the integration of adaptive technology can increase student engagement and help teachers identify learning difficulties in a more targeted manner. However, its implementation still faces various challenges, such as limited infrastructure, technological skills gaps among educators, and cultural resistance to the use of technology in education. Therefore, strategic solutions are needed to overcome these obstacles to ensure the effective and sustainable use of adaptive technology.

As a strategic step, strengthening digital infrastructure in remote areas, teacher training based on the TPACK framework, and educating the public about the benefits of adaptive technology need to be prioritized. In addition, continuous evaluation of the implementation of this technology must be carried out so that it can continue to be adjusted to the needs of students and teachers. Further research is also needed to understand the application of adaptive technology in the context of Indonesia's diverse culture and infrastructure. By implementing these recommendations, it is hoped that adaptive technology can be integrated sustainably in the Indonesian education system, creating more inclusive, flexible, and high-quality learning.

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