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Construction of technology-based and personalized curricula for a more flexible and adaptive education

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Article info

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Abstract

Digital transformation in education opens up excellent opportunities to produce larger, flexible, and adaptive learning. Technologies such as artificial intelligence (AI), augmented reality (AR), and blockchain allow a learning process more tailored to students' needs and abilities. This approach provides a relevant and interactive learning experience and supports the implementation of the Independent Curriculum in Indonesia, which prioritizes flexibility and innovation in teaching. This research explores the potential and challenges of a technology-based curriculum. The results show that this technology effectively improves learning outcomes, but obstacles exist, such as limited infrastructure, lack of training for educators, and student data privacy issues. The synergy between the government, educational institutions, and the private sector is needed. Providing adequate infrastructure, continuous teacher training, and supportive policies will be the key to successfully implementing a technology-based curriculum. If used properly, this technology can make education systems more relevant, inclusive, and ready for future needs.

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1. Introduction

In the era of globalization, future needs, and the digital revolution, the academic world faces significant challenges in continuously adapting to rapid technological changes. Digital transformation has substantially impacted the industrial sector and the education system. Technology in education presents excellent opportunities to enhance administrative management efficiency and expand learning access (Kuhlmann & Heuberger, 2023). However, the journey toward digitalizing education is not always smooth. For instance, research by Zhao et al. (2021) indicates

that integrating information and communication technology (ICT) is a key factor in accelerating education digitalization, especially after the COVID-19 pandemic. The pandemic forced the education sector to transition rapidly to online learning, ultimately highlighting the importance of data literacy, digital communication, and online security as fundamental skills for lifelong learning in the digital era. Although digital education offers great potential, its success heavily depends on factors such as government policies, school culture, and the digital competencies of teachers and students (Herlina et al., 2025). In this context, Khalid et al. (2024) emphasize the importance of integrating digital learning into STEM education as a response to technological advancements. This technology-based learning approach provides opportunities for students to engage in project-based learning, digital simulations, and virtual laboratories, fostering active participation and improving understanding of complex concepts.

However, digital transformation in education still faces significant challenges, such as the digital divide in developing countries and concerns about the decline of face-to-face learning experiences. Often designed with a "one size fits all" approach, traditional curricula accommodate diverse learning needs (Wulandari F., 2020). In Indonesia, these challenges are further complicated by social and geographical diversity, particularly in remote areas with limited educational facilities. Additionally, using native languages in daily life influences material comprehension, as seen in the Minangkabau region, where students are more accustomed to using their local language than formal Indonesian, affecting their learning outcomes (Sukma et al., 2023). The "Merdeka Curriculum" (Independent Curriculum) was introduced, offering a more flexible and student-centered approach. However, its implementation still faces challenges, particularly regarding teachers' understanding of this curriculum's flexibility concept. Many teachers struggle to implement learning tailored to students' needs due to the lack of clear guidelines and adequate training (Paramesthi & Suwartono, 2023). Furthermore, infrastructure readiness and coordination between schools, teachers, and communities in implementing the "Pancasila Student Profile Strengthening Project" remain major obstacles (Marthawati & Setyo, 2024).

In the effort to build a technology-based and personalized curriculum for a more flexible and adaptive education, local schools face quite complex challenges in managing the transition. Shifting from a conventional learning system to a more digital and individualistic approach requires technical and cultural adjustments. Many schools must invest in technological infrastructure, teacher training, and the development of learning content that can be tailored to the needs and interests of each student. The main challenges that arise include inequality in access to devices and the Internet, readiness of human resources, and resistance to change from some educators who are still accustomed to traditional methods. In addition, the process of personalized learning also requires a more flexible and dynamic evaluation system, which is often not yet available in the local school system. Therefore, the success of implementing this curriculum depends on collaboration between schools, the government, and support from the community and parents of students in creating an inclusive and sustainable learning ecosystem.

Thus, although digital education offers significant opportunities to create a more flexible and inclusive learning system, there remains a research gap regarding the effectiveness of technology implementation in personalized learning, especially in Indonesia's social and geographical diversity. Most previous studies have focused more on general technology adoption, with limited exploration of how technology can support differentiated learning for students from diverse backgrounds. Additionally, there is a lack of research on how digital approaches can bridge gaps in education access and how policies can better support teacher readiness and educational infrastructure. This study aims to analyze how digital transformation in education can be effectively implemented to address existing challenges and ensure a more adaptive education system oriented toward student needs in the digital era. Specifically, this research will examine the best strategies

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for utilizing technology to create more inclusive, flexible, and personalized learning tailored to students' needs in various social and geographical conditions. By understanding the key factors contributing to the successful implementation of digital transformation in education, this study is expected to provide more specific and applicable recommendations for policymakers, educators, and educational technology developers.

2. Method

This study used the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach, an international guideline designed to ensure transparency and improve the quality of reporting in systematic reviews and meta-analyses. PRISMA provides a structured framework for searching, filtering, evaluating, and synthesizing relevant literature to answer a specific research question (Rethlefsen et al., 2021). The selection of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method in this study was based on the need for a systematic, structured, and transparent approach to filtering and evaluating relevant literature. The available literature on developing technology-based and personalized curricula is diverse regarding approach, regional background, and findings. PRISMA allows researchers to systematically identify, evaluate, and synthesize these studies with a traceable documentation process, thereby increasing the validity and reproducibility of the study. While practical, other methodologies, such as narrative or scoping reviews, often lack a rigorous and explicit selection framework, leading to selection bias or inconsistencies in data collection. PRISMA provides robust reporting standards and can be used to explain the inclusion and exclusion processes of studies transparently. Therefore, PRISMA was deemed most appropriate to ensure that the literature review in this paper supports the development of evidence-based arguments in building a curriculum that is more adaptive to individual learning needs and developments in educational technology.

In this paper, the data synthesis process was conducted qualitatively, given the diversity of approaches, contexts, and outcomes of the studies reviewed in the systematic review. Qualitative synthesis allows researchers to identify key themes, common patterns, and variations that emerge in implementing technology-based and personalized curricula across educational settings. This approach was chosen because most of the literature reviewed was descriptive and conceptual rather than the result of controlled experiments or quantitative tests. Using a checklist and flowchart consisting of 27 items, PRISMA allows researchers to document each step of the study in detail, from search strategy to data analysis, including inclusion and exclusion criteria. This structured approach ensures transparency in the systematic review.

Figure 1 shows the flow of the literature selection process using the PRISMA diagram for a study on technology-based curriculum development and personalization for a more flexible and adaptive education. This process begins at the Identification stage, where a literature search is conducted through the Google Scholar and ProQuest databases using keywords relevant to the research topic. As a result, 110 journals were found on Google Scholar and 35 journals on ProQuest. Next, enter the Screening stage, where automatic screening is carried out for articles published in the last 4 years. After this process, the number of journals was reduced to 80 from Google Scholar and 20 from ProQuest. Further screening is carried out at the Eligibility stage by automatically filtering relevant titles. After this step, 50 journals from Google Scholar and seven from ProQuest still meet the research criteria. In the final stage, Include, the researcher conducts a manual review of the journals that pass to find the most relevant strategies and data analysis. After an in-depth review, the 25 most relevant journals were obtained to be used as the basis for further analysis in the study. This process shows how a systematic approach helps to filter literature sources to produce high-quality insights efficiently. After the analysis is carried out, this research will have the following strategies The

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following is the prism approach from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses) shown in **Figure 1.**

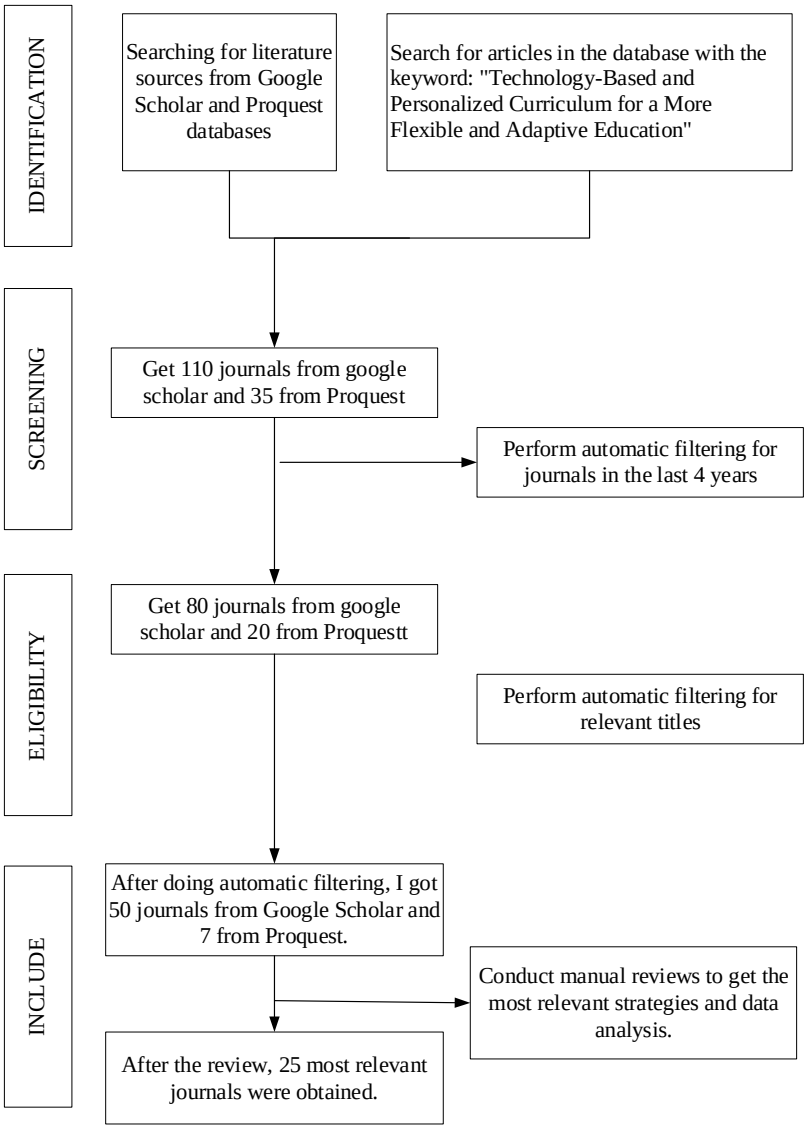

Figure 1. PRISMA (preferred reporting items for systematic reviews and meta-analyses) approach

Basic Definitions and Theories

A technology-based curriculum is an instructional method that incorporates digital tools to enhance interactivity, flexibility, and relevance in learning. Computers, tablets, and digital applications facilitate project-based learning and foster essential 21st-century skills (Viberg et al., 2023). This integration enables personalized learning, where teachers can tailor content to students' individual needs, promoting deeper engagement. Blended learning is widely adopted(Jie & Sunze, 2023). However, challenges such as inadequate infrastructure, lack of teacher training, and resistance to new methodologies remain significant barriers (Viberg et al., 2023). Continuous teacher training is essential to ensure the success of technology-based curricula. Personalized-based curriculum adapts learning processes to students' unique needs, interests, and capabilities, offering flexibility in pace, teaching methods, and content (Shemshack et al., 2021)). Real-time monitoring through innovative technology allows teachers to adjust instruction based on collected

data, enhancing student-centered learning (Tetzlaff et al., 2021). With adequate support from educators, students, and policymakers, this approach can significantly improve learning outcomes and prepare students for future global challenges (Hall & Trespalacios, 2019; Shemshack et al., 2021).

Case Study of Technology-Based and Personalized Learning.

In Western countries, adaptive technology and artificial intelligence (AI) are the foundation for personalized learning, enabling students to adjust their learning paths for improved outcomes. However, limitations in learning autonomy persist, emphasizing the essential role of teachers in facilitating effective technology integration. Universities worldwide utilize augmented reality (AR) and digital twins to enhance project-based learning, particularly in science and engineering disciplines. Digital twins improve comprehension, while AR enhances student confidence and practical skills, making them valuable tools in technology-driven education. Technology increasingly supports inclusive learning in developing countries, such as Indonesia and the Middle East. In East Jerusalem, for instance, digital tools assist special education teachers in developing practical skills.

Studies indicate that technology's effectiveness is independent of age or gender; however, teacher training remains crucial for optimal utilization. AI-driven personalized learning is becoming a global trend, tailoring learning materials to individual student needs for a more meaningful educational experience. However, challenges such as data privacy concerns and inadequate regulations for data security must be addressed through policy development. Meanwhile, blockchain technology is emerging in virtual education to enhance transparency and efficiency in data management. Although in its early stages, blockchain holds significant potential for widespread adoption, pending further research and refinement. Adaptive technology is also revolutionizing online courses, using real-time student data to customize learning experiences. Research suggests this approach improves learning outcomes by up to 40% compared to traditional methods, making it one of the most effective technology-driven educational strategies. In Indonesia, a technology-based and personalized curriculum aligns with the Independent.

The curriculum allows students and educators to select appropriate learning methods. Technologies like AR and adaptive learning platforms personalize educational experiences to meet diverse student needs. AI-powered data analysis further enables teachers to refine instructional content for better learning outcomes (Kurniawan et al., 2025). One notable example is the use of AR in Indonesian classrooms, which enhances conceptual understanding and engagement (Kurniawan et al., 2025). The *Merdeka* Curriculum fully supports such innovations by allowing teachers to adapt strategies based on local resources and student-specific needs (Hiltrimartin et al., 2024).

3. Results and Discussion

Technology has become part of the modern education world. With a more flexible and tailored approach to student needs, augmented reality (AR) and AI make a big difference in how we teach and learn. For example, AR helps students understand abstract concepts interactively and engagingly. It makes it easier for them to understand complex material and increases interest in previously considered difficult subjects (Woolf B.P., 2019). In Indonesia, the use of technology in education is starting to grow, although it still faces various challenges. The Merdeka Curriculum has utilized technology to support personalized learning, primarily through adaptive e-learning platforms. With this approach, students can learn at the pace they want. An inclusive learning environment like this also allows students with special needs to benefit from it (Samsudi et al., 2024). Blockchain technology is also starting to be applied in education as an innovation to manage

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student data with better transparency and security. In some developed countries, blockchain is even used to monitor student progress in real time, allowing teachers to design more effective teaching strategies based on accurate data (Fernández-Caramés & Fraga-Lamas, 2019). On the other hand, AI is a major supporter of learning personalization. AI can analyze student data and suggest materials tailored to their needs.

However, the implementation of AI still faces challenges, especially in terms of protecting student data privacy. Therefore, clear policies and strong regulations are needed to ensure that technology can be used safely and ethically (Khatib Sulaiman Dalam No et al., n.d.). In addition, AR is starting to be widely used in schools in Indonesia, especially in science subjects such as physics and biology. AR makes abstract material easier to understand and more interesting for students, increasing their learning participation. Research even shows that using AR can improve learning outcomes by up to 35%. However, the success of implementing technology like this depends on the readiness of infrastructure and teacher competence. Limited access to technology in remote areas and a lack of training for teachers are significant obstacles to maximizing the potential of technology in education (Tetzlaff et al., 2021). Technology has great potential to produce a more flexible and inclusive education system. With the support of sustainable policies, adequate infrastructure, and intensive teacher training, technologies such as AR, AI, and blockchain have tremendous potential to change the education paradigm in Indonesia. If used correctly, this technology can be a significantly advantageous tool for solving educational problems in the contemporary era. One of the most important innovations in education today is the personalization of learning. The implementation of technology-based and personalized curricula, although promising increased flexibility and adaptability in the learning process, faces significant challenges when implemented in areas with limited infrastructure and resources. Schools in remote areas often lack access to a stable internet network, have minimal availability of digital devices, and have limited teaching staff competent in using educational technology. These factors not only hinder the integration of technology into the curriculum but also risk widening the learning gap between regions. A contextual and adaptive approach needs to be designed to address these challenges. The curriculum implementation strategy should include providing offline-based learning technology that allows local access to materials without relying on an internet connection. In addition, strengthening teacher capacity through digital literacy training based on local needs must be a priority, especially in developing pedagogical skills that support personalization. A collaborative approach is also essential, such as establishing partnerships with technology institutions, local governments, and community organizations to provide technical and financial support.

Implementing technology-based and personalized curricula in Indonesia shows excellent potential to increase the flexibility and adaptability of learning. However, the success of its implementation varies wildly, depending on the readiness of the infrastructure and human resource capacity in each school. Based on data from the Central Statistics Agency (BPS) in 2018, as many as 62.41% of schools in Indonesia have internet access through fixed broadband connections, while the rest still rely on mobile broadband (34.85%) or satellite connections (4.01%). However, only around 33.67% of students use the Internet at school as a learning tool, and only 10.10% of teachers have adequate competence in Information and Communication Technology (ICT). It reflects a digital divide between the potential of technology and the readiness for implementation in the field. As a case study, in Medan, a high school has successfully integrated technology through a digital learning platform that includes interactive videos and online quizzes. The results showed a significant increase in student participation and learning quality.

Meanwhile, in remote areas such as Batang Kuis District, North Sumatra, the digitalization of education has begun to be implemented through offline learning devices that do not depend on an internet connection. This approach is a contextual solution that allows learning access to continue

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even with limited infrastructure. Another study in high schools in Salatiga showed that using audio-visual media and interactive applications has significantly improved student learning achievement.

Implementing technology-based education policies in Indonesia and other developing countries has shown various practical approaches that can be used as examples to strengthen the development of adaptive and flexible curricula. One prominent policy is the "Merdeka Belajar" program launched by the Indonesian Ministry of Education, Culture, Research, and Technology. This program encourages digital platforms such as Rumah Belajar and Merdeka Mengajar to provide teaching materials tailored to students' needs and teachers' abilities. In other developing countries such as India, the Digital India program has succeeded in improving digital literacy in rural schools by providing hardware and technical training for teachers. These policy examples show that the success of technology integration depends on the availability of tools and systemic support, such as ongoing training for educators and active participation of local governments. To sustain these policies over the long haul, it is necessary to consider aspects of sustainable funding and mechanisms for maintaining technological infrastructure. The government must establish a medium-term budget scheme allocated explicitly for developing and maintaining educational technology and encourage collaboration with the private sector. In addition, teacher training must be an ongoing process, not just a one-time initiative, so that the digital transformation in education is genuinely sustainable. Updates to systems, software, and pedagogical methods must also be carried out periodically to maintain the relevance and effectiveness of technology-based curricula amidst changing times. This policy approach, if implemented consistently, will help strengthen the foundation of future education that is inclusive and adaptive to change.

In addition, AR is starting to be widely used in schools in Indonesia, especially in science subjects such as physics and biology. AR makes abstract material more understandable and engaging for students, increasing their learning participation. Research has even shown that AR can improve learning outcomes by up to 35%. However, the success of implementing technology like this depends on the readiness of the infrastructure and the teachers' competence. Limited access to technology in remote areas and lack of training for teachers are the main obstacles to maximizing the potential of technology in the world of education (Tetzlaff et al., 2021). Technology has great potential to produce a more flexible and inclusive education system. With sustainable policy support, adequate infrastructure, and intensive teacher training, technologies such as AR, AI, and blockchain have tremendous potential to change the educational paradigm in Indonesia. If used correctly, this technology can be an indispensable tool to solve educational problems in the contemporary era. One of the most important innovations in education today is the personalization of learning. This method allows for a learning experience tailored to students' needs, interests, and abilities. Technologies such as big data and AI, for example, can provide direct feedback to students, helping them learn faster and become more motivated. AI and adaptive technology are now key pillars in supporting personalized learning. This technology can recognize students' learning patterns, understand their difficulties, and provide the right materials to help them improve their learning outcomes. The study emphasizes that adaptive technology-based learning platforms can significantly improve learning outcomes compared to traditional methods (Shemshack et al., 2021). In addition, new technologies such as digital twins and blockchain are also beginning to be applied to create a more efficient and transparent learning environment.

However, the journey to fully effective personalization of learning is not easy. One of the main challenges is protecting the privacy of student data. In data collection and processing, concerns often arise about how the data will be used and secured. In addition, the limitations of technological infrastructure in various regions and the lack of teacher training are obstacles to the widespread application of personalized learning. Therefore, ongoing training for teachers is essential to ensure the success of this approach (Dehbi et al., 2025; Santos et al., 2024). In the future, technologies

such as AI and big data are expected to bring about significant educational changes, creating a more inclusive and equitable system. However, to realize this potential, careful planning and further research are urgently needed to address ethical, privacy, and infrastructure challenges. If used wisely, this technology will make learning more effective and provide students with a unique, meaningful learning experience (Jie & Sunze, 2023).

Gaps and Opportunities

Technology in education in developing countries still faces various real obstacles. One of the main problems is the inequality of problems with technological infrastructure. Computers and internet connections are available in many schools, especially in remote areas. As a result, students in these areas find it challenging to get the same benefits from educational technology innovations compared to those who live in areas with better facilities (Dehbi et al., 2025). It is not only about infrastructure; technological literacy is also a big challenge. Many teachers have not received sufficient training to use technology effectively in teaching and learning.

Meanwhile, students often do not have the skills to utilize technological devices productively. It causes existing technology not to be used, so its benefits in improving learning are not felt optimally (Santos et al., 2024). Stein & Sim (2020) stated that the limited understanding of individuals towards technology creates a gap in the optimal use of ICT at the doctoral level (Castro Benavides et al., 2020). Additionally, many higher education institutions fail to implement digital strategies effectively, so personalization of learning is not realized. Both emphasized the need for holistic strategies, adequate infrastructure, and intensive training to bridge this gap. In addition, budget constraints are another significant obstacle. Many schools in developing countries operate with constrained resources, making buying new devices or updating outdated technology complex. Operational costs such as internet subscriptions and device maintenance are also difficult to meet. This problem further widens the gap in access to educational technology in various regions (Ning et al., 2024). With technology-based curriculum innovation, there is an excellent opportunity to improve the quality of education in Indonesia. Technologies such as big data, artificial intelligence (AI), and the Internet of Things (IoT) allow learning to be tailored to the needs and abilities of each student. Adaptive technology, for example, allows for more personalized learning so that students can learn in the way that suits them best (Fernández-Caramés & Fraga-Lamas, 2019). This approach also creates more inclusive opportunities, allowing all students to access high-quality education regardless of their background.

Technology paves the way to develop more engaging and interactive ways of learning. Through simulations and real-world applications, learners not only understand theory but also acquire pragmatic skills that are relevant to real-world needs. Explained that technological advances not only add complexity but also provide more autonomy in work through the use of automated systems and digital devices. It shows the need for a curriculum that integrates mastery of technology and time management skills to support lifelong learning. (Wu, 2024).

Additionally, technology helps students adjust to different learning styles and prepares them for challenges in the workplace (Suwastika et al., 2024). In addition to learning, technology also offers innovations in the educational evaluation process. Digital-based evaluation systems allow for faster, fairer, and more in-depth assessments. The data from the evaluation results may be used to identify student's weaknesses and strengths so that learning can continue to be improved. Blockchain technology can even ensure the security and transparency of students' academic data, creating trust in education management (Shuhaimi et al., 2025). Cooperation between the government, educational institutions, and the private sector is needed. The government must ensure the equitable availability of infrastructure, while educational institutions must design a relevant and timely curriculum. The private sector can help by providing technology and supporting

training for teachers. With strong collaboration, Indonesia can leverage technology to create a curriculum that is not only relevant but can also prepare students to face the future confidently.

Practical Implications

Integrating technology into education involves much more than providing devices, internet access, or modern classrooms. While infrastructure such as hardware and connectivity is a crucial first step, it cannot transform teaching and learning experiences. Well-designed policies and strategic planning must accompany it. These policies must address how educators and students should implement, maintain, and use technology effectively.

According to Schmid and Petko (2019), one of the key elements of successful technology integration is implementing a fully integrated technological system that supports personalized learning. Personalized learning tailors educational experiences to meet individual students' needs, preferences, and learning paces. For this approach to work effectively, the supporting technology must be comprehensive—it should handle a wide range of functions, such as lesson planning, tracking student progress, delivering instruction, and assessing learning outcomes. Without such a system, personalized learning remains challenging to achieve in practice.

Unfortunately, the reality is that many schools—especially those in under-resourced or rural areas—do not have access to these integrated systems. They may lack the funding, technical expertise, or policy support to adopt and maintain advanced technology platforms. As a result, the full potential of technology to enhance learning remains untapped in many educational settings. Bridging this gap requires infrastructure development, supportive educational policies, teacher training, and long-term planning. Therefore, education policies need to be focused on providing relevant and affordable technology, especially for schools in regions with limited resources. Alamri et al., 2020) recommend developing learning technology models that support personalization and are flexible to apply in various educational contexts. With this approach, more inclusive and effective learning can be realized.

On the other hand, intensive training for educators is the key to maximizing the benefits of technology in learning. Many teachers still face challenges in understanding and using adaptive technology. Herawati (2023) emphasizes the importance of a technology-based curriculum that includes the function of recording and evaluation and supports lifelong learning. Training like this can help teachers use technology more confidently and encourage them to create learning experiences relevant to students' needs. In the context of developing countries, Major et al. (2021) noted that educational technology has a very positive impact, especially if teachers get adequate training to make the most of it. In addition, developing a personalized curriculum is an important priority in education policy. This curriculum must utilize adaptive technologies, such as artificial intelligence (AI) and big data, which can adapt learning to each student's needs and abilities (Tetzlaf et al., 2021). It highlights that a technology-based curriculum must be dynamic and able to keep up with the changing traits of constantly changing students. This approach allows teaching to be more relevant and personalized and helps students prepare for the challenges of the modern world of work. With strong policies, thorough educator training, and technology-based curricula, education can transform to be more inclusive, efficient, and in line with the standards of the times.

4. Conclusion

Technology-based and personalized education programs provide an opportunity to create a more flexible and student-centered learning environment. Integrating Artificial Intelligence (AI), Augmented Reality (AR), and Blockchain enables a customized learning experience, allowing students to engage in more interactive and meaningful learning. This approach empowers students

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to learn at their own pace and facilitates educators to adjust teaching methods based on the local context and individual student potential. These technologies foster innovative, inclusive, and adaptive learning within the Merdeka Curriculum framework. The development of technology-based and personalized curricula for more flexible and adaptive education has great potential to improve the quality of learning in Indonesia. However, the success of its implementation is greatly influenced by real challenges on the ground, especially in areas with limited infrastructure. Therefore, future research is recommended to focus more on developing contextual solutions that can address these obstacles. It includes exploring low-tech models that can be effectively implemented in remote areas, sustainable funding strategies, and designing teacher training programs that are adaptive to technological developments. In addition, there is a need for longitudinal studies to evaluate the long-term impact of implementing digital education policies across geographic and social conditions. This approach is expected to encourage the formation of policies and curricula that are not only technology-based but also inclusive, equitable, and sustainable across the country.

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