

INTEGRATION OF ARTIFICIAL INTELLIGENCE IN ADAPTIVE LEARNING: OPPORTUNITIES AND CHALLENGES FOR TEACHERS IN THE ERA OF EDUCATION 5.0

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Abstract

The integration of Artificial Intelligence (AI) in adaptive learning represents a transformative shift in Indonesia's basic and secondary education system, aligning with the vision of Education 5.0 that emphasizes human-centered and technology-empowered learning. AI-driven adaptive systems have demonstrated the ability to personalize learning pathways, automate formative assessment, and provide data-supported instructional recommendations that enhance student outcomes. This study employs a systematic literature review to analyze the opportunities and challenges facing Indonesian teachers in implementing adaptive AI at the K–12 level. Findings show that while AI enables differentiated instruction, timely remediation, and deeper learning engagement, successful adoption depends significantly on teachers' digital pedagogical literacy, data-informed decision-making, and ethical understanding of algorithmic systems. Key challenges include unequal infrastructure, varying teacher readiness, privacy risks in student data management, and limited policy frameworks. The study concludes that AI should serve as a pedagogical partner rather than a replacement for teachers, reinforcing the irreplaceable role of educator empathy, socio-emotional support, and professional judgment. Strategic competence development, equitable digital access, and clear regulatory guidance are essential to ensure that AI integration strengthens educational equity and instructional quality within Indonesia's Education 5.0 ecosystem.

Keywords : Artificial Intelligence; Adaptive Learning; Teacher Competencies; Education 5.0; Digital Pedagogy

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1. Introduction

The development of artificial intelligence (AI) has fundamentally changed modern learning design, especially through adaptive learning systems that adjust content, pace, and instructional pathways to learners' abilities. This approach aligns with the vision of Education 5.0, which emphasizes human-machine collaboration to create personalized, data-driven, and student-centered learning environments. UNESCO (2022) highlights that AI enhances equitable access, personalization, and assessment efficiency, while globally the educational AI market continues to expand significantly (Gowda, 2023). In Indonesia, policies under Merdeka Belajar encourage the integration of learning analytics and adaptive platforms across school levels (Kemendikbud, 2023).

AI-driven adaptive learning has shown strong potential to support differentiated instruction by analyzing student performance data and recommending tailored learning activities. International studies indicate notable gains in academic outcomes and student engagement (Jayanthi et al., 2023; Gunawan & Danika, 2023). Indonesian digital platforms such as Rumah Belajar, Zenius, Ruangguru, and Quipper have begun incorporating machine-learning features to support adaptive pathways, though implementation remains gradual (Pranata & Santoso, 2023). This reinforces the importance of teacher readiness in managing AI-supported personalization.

In school contexts, AI increasingly serves not only as an instructional tool but also as a pedagogical partner that strengthens teachers' capacity to design personalized and data-informed lessons. Research shows a shift in teacher roles toward facilitators and mentors within AI-supported environments (Eliwatis et al., 2022), consistent with the Education 5.0 emphasis on creativity, character, and human-centered learning. Indonesian teachers with stronger digital and analytical competencies have demonstrated greater effectiveness in applying differentiated learning (Al-Emran & Al-Sharafi, 2022), underscoring the need for enhanced technopedagogical training.

However, several challenges continue to hinder AI integration in Indonesian basic education. Teachers' digital literacy gaps remain substantial, with many educators still unfamiliar with adaptive learning concepts and data-use techniques (Pusdatin Kemendikbud, 2023; Antasari, et al 2025). Infrastructure disparities also affect AI adoption, particularly in 3T regions where internet access and device quality are limited (APJII, 2023; Dey & Sahoo, 2025). In parallel, ethical concerns—including algorithmic bias, data privacy risks, and student vulnerability—remain critical considerations requiring stronger governance frameworks (Supriya et al., 2024; Hendrawan & Yusuf, 2023).

Nevertheless, the potential benefits of AI for Indonesia's education system remain substantial. With millions of students and teachers nationwide, adaptive AI platforms offer opportunities for real-time assessment, individualized remediation, and improved achievement in core subjects (Al-Emran & Al-Sharafi, 2022). AI-supported adaptive learning also aligns with the goals of the Merdeka Curriculum and the P5 project in strengthening personalized, inclusive, and formative learning practices (Taufik & Syahril, 2024).

Despite a growing body of global literature on AI in education, existing studies tend to focus on general pedagogical shifts or technology frameworks without examining practical teacher-level challenges in the Indonesian school context (Eliwatis et al., 2022; Supriya et al., 2024; Al-Emran & Al-Sharafi, 2022). This creates a research gap concerning how AI integration specifically shapes teacher competencies, decision-making practices, and adaptive learning implementation in primary and secondary education.

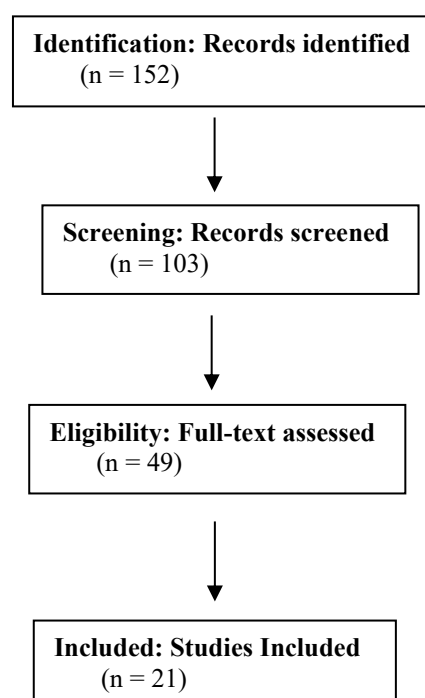
Addressing this gap, the present study integrates pedagogical, technological, and contextual perspectives to examine how AI affects teachers' roles, skills, and instructional practices in Indonesia. This study aims to analyze how AI integration shapes teacher competence and classroom practices in Indonesia.

2. Method

This study uses the Systematic Literature Review (SLR) method to comprehensively identify and analyze scientific literature related to the integration of artificial intelligence (AI) in adaptive learning and its implications for teacher competence at the elementary to high school levels in Indonesia. The SLR approach was chosen because it is capable of producing a strong scientific synthesis through a systematic, transparent, and highly replicable process of selecting, evaluating, and integrating research findings, as recommended in modern educational and educational technology research (Snyder, 2019). In addition, the SLR method allows researchers to trace research trends, identify academic gaps, and map conceptual frameworks related to the role of teachers in AI-based learning ecosystems, which are relevant in the context of Education 5.0 transformation (Xiao & Watson, 2019).

The data collection procedure was carried out through a systematic search of reputable scientific databases, namely Scopus, Web of Science, ERIC, SpringerLink, and Google Scholar. The article search covered the period 2015–2024 to ensure the literature was up to date in response to developments in AI technology in education. The keywords used included combinations of terms such as “AI in education,” “adaptive learning,” “teacher readiness AI,” “Education 5.0 pedagogy,” and “AI implementation in Indonesian schools.” The inclusion criteria included: (1) indexed and peer-reviewed journal articles, (2) research related to AI-based adaptive learning, (3) a focus on the role or readiness of teachers, particularly at the primary and secondary education levels, and (4) contextual relevance to the education systems of Indonesia or developing countries. Articles that did not provide full access, were not scientific studies, or only discussed technical aspects without pedagogical relevance were excluded from the analysis, in accordance with the guidelines for selecting academic literature quality (KitJayanthiham et al., 2020).

The data were analyzed using a thematic analysis approach, following the conceptual steps of Braun and Clarke (2021), including text familiarization, literature coding, identification of main themes, and the formation of a critical narrative synthesis. The themes that emerged included teachers' digital competency readiness, the use of adaptive learning data, challenges in technology implementation, and pedagogical and ethical implications for elementary to high school teachers. Validity was strengthened through cross-comparison across studies and triangulation of findings between databases. This procedure ensured that the interpretation of findings was objective, evidence-based, and consistent with academic research standards in the field of educational technology.



3. Results and Discussion

Transformational Role of Artificial Intelligence in Adaptive K-12 Learning

The integration of artificial intelligence in adaptive learning systems has become a critical point of change in the educational paradigm at the elementary and secondary school levels in Indonesia. At a fundamental level, AI provides the ability to collect, analyze, and interpret student learning data in real time, thereby providing learning recommendations tailored to each student's ability level, learning style, and pace. In line with the idea of Education 5.0, technology is not merely a learning aid but a pedagogical partner that strengthens human agency in the learning process (Nazar et al., 2024). Research by Jayanthi et al. (2023) shows that adaptive learning systems can increase concept retention by up to 25% in elementary school students with mathematical learning difficulties through personalized learning paths. In a similar context, Umirzakova et al., (2023) prove that AI-enhanced feedback systems improve the accuracy of remediation and the engagement of secondary students in competency-based learning. This shows that AI technology supports learning differentiation, which has been a challenge for teachers in large classes, especially at the elementary and secondary levels, where student abilities are highly heterogeneous.

The Indonesian context reinforces the urgency of implementing AI-based adaptive approaches. The implementation of the Merdeka Curriculum requires flexible, personalized, and responsive learning tailored to individual needs through pedagogical differentiation or scaffolding (Ministry of Education and Culture, 2023). However, a study by Pranata and Santoso (2023) found that although teachers understand the concept of differentiation, 67% of elementary and high school teachers are unable to implement it consistently due to limitations in assessment time, student information analysis, and teaching aids. The presence of AI in adaptive learning fills this gap through its ability to automate student response analysis, achievement level mapping, and the provision of remedial and enrichment materials on an individual basis. Thus, AI is not only a technological tool, but also an enabler of personalized pedagogy that accelerates the implementation of student-centered learning in Indonesia.

However, the integration of AI in learning is not without epistemological and pedagogical challenges. Teachers often worry about the dominance of technology in instructional decision-making, leading to the perception that AI may reduce teachers' professional autonomy (Supriya et al., 2024). In practice, AI systems in primary and secondary education do not replace teachers' intuition but act as instructional assistants that provide data and recommendations based on statistical models, while the final decision remains in the hands of the teacher. Zhang et al. (2021) emphasize that teachers in the AI ecosystem need to maintain pedagogical sovereignty, which is the ability to critically manage algorithmic information and interpret technological recommendations based on students' socio-emotional needs and cultural contexts. Thus, the effectiveness of AI in adaptive learning depends on teachers' competence in conducting AI-mediated instruction reflectively.

The process of implementing AI in schools must also consider the readiness of the educational technology ecosystem. Research by Ratnaningsih and Sari (2022) shows that differences in access to devices and the internet in Indonesian schools remain a major obstacle to large-scale AI implementation. Schools in urban areas such as Jakarta and Bandung have greater access to digital adaptive platforms, while schools in rural areas face bandwidth constraints, device limitations, and a lack of technical support. Therefore, AI implementation strategies in education must consider the aspect of infrastructure equity as part of digital justice (UNESCO, 2022). This is important considering that Education 5.0 emphasizes inclusive learning and equitable access to innovative technologies.

To clarify the role of AI in adaptive learning for elementary to high school students, the following table summarizes its key features and pedagogical implications.

Table 1. Core Functions of AI in Adaptive K-12 Learning and Educational Benefits

AI Function	Learning Benefits	Pedagogical Implication	Source
Personalized content recommendation	Matches content to student ability	Supports differentiated learning pathways	Jayanthi et al. (2023)
Reatime performance analytics	Tracks progression	Enables mastery intervention & remediation	Xu & Wang (2022)
Automated feedback	Immediate corrective guidance	Enhances formative assessment practices	Holmes et al. (2022)
Intelligent tutoring	Scaffolds learning difficulties	Extends teacher capacity in large classrooms	Zhang et al. (2021)

Although the benefits are enormous, it is important to highlight that technology alone does not guarantee the success of adaptive learning. The effectiveness of AI is greatly influenced by the pedagogical readiness of teachers, the learning culture of students, and institutional support from schools. A study by Azhari and Fadhilah (2023) concluded that investing in technology without investing in technopedagogical capacity building results in superficial utilization, where teachers only use AI as a substitute for manual quizzes, rather than as a learning analytics system. In other words, AI requires a strong pedagogical vision in order to produce a transformational impact. In the Indonesian context, teacher training approaches must prioritize data literacy for teaching, adaptive intervention management, and AI-ethics awareness so that the digital transformation of schools is in line with humanistic educational principles.

Overall, AI in adaptive learning creates opportunities to expand the effectiveness of learning differentiation on a large class scale and supports schools in achieving future-oriented education. However, the technology will only reach its maximum potential if teachers hold a strategic position as directors of learning experiences and guardians of the balance between artificial intelligence and humanity in the learning of primary and secondary school students.

Teacher Competency Transformation in the AI-Driven Education 5.0 Landscape

The integration of artificial intelligence in adaptive learning shifts the paradigm of teacher professional competency, from mere conveyors of knowledge to learning architects who strategically utilize technology to design personalized and meaningful learning experiences. In the Education 5.0 era, artificial intelligence is positioned not to replace teachers, but to expand their capacity to manage student diversity, conduct continuous assessment, and develop student creativity and character (Nazar et al., 2024). This transformation requires teachers to master technological pedagogical content knowledge (TPACK), in which AI is an important element in the integration of learning technology (Al-Emran & Al-Sharafi, 2022). However, beyond technological mastery, teachers need to develop AI pedagogical reasoning, which is the ability to make instructional decisions based on adaptive system recommendations while considering the socio-emotional aspects and human values of elementary and secondary school students.

In the context of Indonesian education, improving teachers' digital competence is a national priority articulated through the Guru Penggerak (Teacher Activator) program, the Merdeka Mengajar (Freedom to Teach) Platform, and various educational ICT training programs. However, findings by Zohuri & Mossavar-Rahmani, 2024 indicate that the development of teachers' digital competencies is still predominantly at the level of operational digital literacy, such as the use of video conferencing platforms, LMS systems, and digital quiz applications, while analytical and AI-pedagogical literacy is still uneven. Teachers in many regions do not yet have the optimal ability to interpret learning analytics dashboards, conduct data-driven learning interventions, or design personalized instruction flow based on system recommendations. This competency gap emphasizes that teacher capabilities in the Education

5.0 era are not limited to operating technology, but also include understanding the epistemological and pedagogical implications of AI in adaptive learning.

In addition, teachers must be able to maintain a balance between algorithms and empathy. Although AI can map learning patterns, provide performance predictions, and recommend remedial materials, it cannot capture the emotional and social nuances experienced by students. Research by Zhang et al. (2021) highlights that the best teaching decisions in primary and secondary education still require human sensitivity in reading the context of students' motivation, family pressures, self-confidence, and social dynamics. In practice, teachers often became the center of students' emotional recovery after the pandemic, especially at the elementary school level (Pranata & Santoso, 2023). Therefore, the development of empathetic–AI balanced pedagogy has become a core competency requirement for teachers, ensuring that adaptive learning does not obscure the human aspects of students.

Ethical challenges also play a major role in the transformation of the teacher's role. The use of AI raises issues of algorithmic bias, children's data privacy, and the risk of tracking labels that can pigeonhole students based on predictive results. Holmes et al. (2022) emphasize that learning recommendation systems can inadvertently reinforce inequality if they are not accompanied by critical supervision from educators. In the Indonesian context, the implementation of the Personal Data Protection Law (PDP Law) is still in the process of being adapted to the basic education ecosystem, making the role of teachers as data guardians increasingly important (Hendrawan & Yusuf, 2023). Teachers need to understand the ethical principles of data use, ensure the security of student information, and resist complete dependence on algorithmic recommendations without deep pedagogical reflection.

In the framework of competency development, teacher professional learning must be evolutionary and continuous. AI enables personalized learning for students, but ironically, the teacher competency development model in Indonesia still relies heavily on mass and one-way learning. A study by Sudrajat & Marlina (2023) emphasizes that continuous training based on simulated teaching, AI-supported instructional coaching, and professional learning communities are more effective in building teachers' technopedagogical capacity. Teacher training must be directed towards a practice-based mastery cycle, namely learning, trying, reflecting, and then improving adaptive teaching strategies. Otherwise, teachers will become passive users of technology, rather than guides of technological intelligence for student progress.

Teachers' readiness to face the AI era is also closely related to their psychological well-being and workload. The implementation of new technology can cause stress, especially when teachers feel that their abilities lag behind the digital systems being used. Research by Ratnaningsih & Sari (2022) shows that some teachers feel anxious about the potential of being “replaced by machines,” especially in schools that require the routine use of analytical dashboards. As a solution, school leadership needs to adopt a transformational–supportive leadership approach that provides space for adaptation, mentoring, and collaboration among teachers in utilizing AI. When teachers feel supported and involved in the digital transformation process, resistance decreases and learning innovation runs more organically (Li & Wong, 2022).

To provide a clearer framework, the following table summarizes the core competencies of teachers in AI-based adaptive learning in the Education 5.0 era.

Table 2. Core Teacher Competencies for AI-Driven Adaptive Learning

Competency Domain	Description	Key Teacher Role in K-12 AI Context
AI-Pedagogical Literacy	Understanding how AI tools affect learning decisions	Selecting, interpreting & validating AI recommendations
Data-Informed Instruction	Using learning analytics for interventions	Designing personalized learning pathways
Digital-Ethical Awareness	Protecting student data & addressing bias	Ensuring safe, fair & transparent AI use

Socio-Emotional Facilitation	Supporting emotional needs beyond AI scope	Maintaining empathy, belonging & motivation
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Thus, the integration of AI in elementary to high school education requires a comprehensive reconstruction of teachers' competencies: technical, pedagogical, ethical, and emotional. Teachers are no longer mere users of platforms, but rather guides of technological evolution in human learning environments. The future of adaptive learning in Indonesia will be determined by teachers' ability to manage the symbiotic relationship between artificial intelligence and human intelligence, so that students are not only academically intelligent, but also excel in character, creativity, and social ethics.

Policy, School Ecosystem, and Implementation Readiness Toward AI-Supported Education 5.0 in Indonesia

The successful integration of artificial intelligence in adaptive learning at the elementary to high school levels depends not only on the readiness of teachers and technology, but also on the governance of educational institutions, national policies, infrastructure readiness, and school culture in accepting change. Schools are social ecosystems where educational actors including teachers, principals, students, parents, and educational staff maintain their interact continuously. Therefore, the development of an inclusive, collaborative, and innovative school ecosystem is an important pillar in the application of AI and adaptive learning approaches. As stated by UNESCO (2022), AI-based education cannot work optimally in an environment that still maintains hierarchical control patterns and a lack of collaborative culture. In Indonesia, educational transformation through the Merdeka Belajar (Freedom of Learning) policy has encouraged changes in school organizational structures towards more flexible and autonomous models. However, a study by Lopian and Yusuf (2023) shows that some schools still adopt a bureaucratic and administrative culture that is less responsive to technological innovation. Thus, institutional readiness is a critical factor that needs to be strengthened systematically.

In addition to school governance, the readiness of digital infrastructure also determines the success of AI-based adaptive learning. APJII (2023) data shows that national internet penetration has increased to 78.19%, but the technological access gap between urban areas and 3T regions remains significant. This has a direct impact on the gap in schools' ability to access adaptive learning platforms and supporting devices such as tablets, laptops, and stable internet connections. A study by Ratnaningsih and Sari (2022) shows that schools in urban areas tend to be able to implement adaptive digital media more effectively than schools in rural areas, which still rely on minimal ICT infrastructure. This disparity raises concerns about the emergence of a digital learning divide, where students in certain regions have greater access to adaptive learning than other students. To realize an inclusive Education 5.0, the government needs to strengthen school digitization and infrastructure distribution programs to ensure that all students have equal opportunities.

Education policy also plays a strategic role in encouraging the adoption of AI in schools. The Indonesian government, through the Ministry of Education and Culture, has released various education digitization policies, including the provision of the Merdeka Mengajar (Freedom to Teach) Platform, the expansion of the Sekolah Penggerak (School Movement) program, and the digitization of libraries. However, specific guidelines on the use of AI in primary and secondary education are still in their infancy. According to Hendrawan and Yusuf (2023), the regulatory framework related to child data privacy, digital identity protection, and algorithm transparency is still limited in school administrative guidelines. Without adequate ethical guidelines and technical regulations, the use of AI technology in schools risks neglecting the principles of data security and technological fairness. Thus, an educational regulatory sandbox is needed, which allows schools to experiment with AI under the supervision of adaptive and gradual policies, while complying with personal data protection regulations and national educational technology ethics.

The cultural factor of school collaboration is also a core element in the successful integration of AI. A school culture that is open to innovation, supports professional discussion, and provides room for experimentation for teachers has been proven to accelerate the success of pedagogical transformation (Taufik & Syahril, 2024). Conversely, a school environment that treats innovation as an administrative burden or merely a formalistic project tends to trigger resistance from teachers. Teachers who feel forced to adopt technology without adequate support are prone to experiencing technological stress and resistance to digital platforms (Antasari, et al 2025). Therefore, school cultural transformation must focus on empowering teachers as agents of change, not just policy implementers. Internal mentoring mechanisms, professional learning community (PLC) development, and inter-school collaboration through digital platforms can create a space for collective growth for teachers in mastering AI-based pedagogy.

In addition, parental and community involvement is an important component in building an AI-based adaptive learning ecosystem. In many elementary schools, parental involvement helps ensure that the use of adaptive learning technology is consistent at home and at school. However, parents' digital literacy in Indonesia still varies greatly, and some parents have concerns about their children's exposure to technology and privacy (Pranata & Santoso, 2023). Therefore, technology socialization strategies must include educating parents about the benefits, risks, and procedures for the responsible use of AI in their children's learning. A whole-community digital literacy approach is an important prerequisite for educational transformation to take place not only in the classroom but also as part of a lifelong learning ecosystem for the community.

Furthermore, the successful implementation of AI in schools requires cross-sector collaboration between the government, the private sector, edtech, academics, and international organizations. Multi-stakeholder collaboration models have been proven to drive educational innovation in countries such as South Korea and Singapore (UNESCO, 2022). In Indonesia, collaboration between the Ministry of Education and Culture, educational technology providers, universities, and pilot schools can accelerate the adaptation of AI in adaptive learning through direct implementation research, intensive practice-based training, and the development of local software that suits the learning characteristics of Indonesian students. This approach supports the creation of an Education 5.0 ecosystem that does not only rely on global products but is also capable of producing educational technology innovations based on local wisdom and national needs.

However, the challenges of implementing AI in primary and secondary education also include sustainability issues. Many digital education innovations in Indonesia only run in the pilot phase and do not continue due to funding constraints, lack of long-term policy support, or limited technical capacity of schools (Pedro et al., 2019). To overcome this, an AI sustainability model design is needed that includes sustainable financing, system maintenance, and consistent capacity building for teachers and school management. This approach ensures that AI integration is not a temporary program, but part of a sustainable education system that is adaptive to technological evolution.

From a future perspective, the development of an AI-based school ecosystem needs to be directed towards a future-ready school model, namely a school that is able to adapt to technological changes, facilitate critical thinking, creativity, collaboration, communication, digital literacy, and ethical literacy competencies. This future school model prioritizes personalized learning, collaborative projects, psychological well-being support, and data-based authentic assessment. In line with the Education 5.0 vision, schools must become spaces where technology reinforces human values rather than replacing them. Thus, the integration of AI in adaptive learning in elementary to high schools in Indonesia will achieve its ultimate goal: to create a generation of students who are intelligent, adaptive, ethical, and ready to compete in the era of the knowledge economy and digital intelligence.

4. Conclusions and Suggestions

The integration of artificial intelligence in adaptive learning at the elementary to high school levels in Indonesia is an important milestone in the transformation of education towards the Education 5.0 era, where technology acts as a catalyst for improving the learning experience as well as a pedagogical partner for teachers. The research findings confirm that AI can support personalized learning, accelerate formative assessment, and provide more targeted learning interventions based on individual student needs. However, the success of implementation cannot be understood solely as technological innovation, as this process is greatly influenced by teacher readiness, institutional support from schools, adequate digital infrastructure, and comprehensive education and data protection policies. Technology only provides optimal value when accompanied by teachers' pedagogical competence and professional ethics in managing AI recommendations in a reflective and humanistic manner, so that holistic educational goals can be achieved sustainably.

In line with the findings of the discussion, the main challenges of integrating AI into adaptive learning in Indonesian schools include gaps in teachers' digital literacy, infrastructure disparities between regions, school cultural readiness, and awareness of the ethics of student data use. Teachers play a strategic role as instructional decision-makers who interpret algorithmic information while maintaining students' social-emotional sensitivity. Therefore, teacher capacity building needs to focus on data literacy, mastery of adaptive pedagogy, reflective skills, and digital ethics competencies. On the other hand, schools need to build a collaborative culture, strengthen visionary leadership, and provide technology-based experimental spaces so that innovation can be organic and sustainable.

This is an important foundation so that AI integration does not result in passive dependence, but rather encourages educational transformation that favors meaningful learning. Based on the results of the study, several recommendations can be made to strengthen the application of AI in adaptive learning in Indonesia. First, the government needs to develop a national guideline framework on AI integration for primary and secondary education, including support for child data privacy regulations and the development of an inclusive digital ecosystem.

Second, educational institutions need to develop practice-based continuous training models, such as AI-assisted coaching and professional learning communities for teachers, to strengthen technopedagogical literacy. Third, schools need to ensure the availability of adequate digital infrastructure and strategies to equalize access to technology for all students. Finally, all education stakeholders such as teachers, schools, government, and the technology industry, must work together to build an AI-based education model that upholds human values, creativity, morals, and character, so that Indonesia's young generation can develop academically, emotionally, and socially in the digital landscape of the future.

Bibliography

- Adeleye, O. O., Eden, C. A., & Adeniyi, I. S. (2024). *Innovative teaching methodologies in the era of artificial intelligence: A review of inclusive educational practices*. World Journal of Advanced Engineering Technology and Sciences, 11(2), 069–079.
- Agarwal, V., Verma, P., & Ferrigno, G. (2025). *Education 5.0 challenges and sustainable development goals in emerging economies: A mixed-method approach*. Technology in Society, 81, 102814.
- Ahmad, S., Umirzakova, S., Mujtaba, G., Amin, M. S., & Whangbo, T. (2023). *Education 5.0: Requirements, enabling technologies, and future directions*. arXiv preprint arXiv:2307.15846.
- Al-Emran, M., & Al-Sharafi, M. A. (2022). *Revolutionizing education with industry 5.0: Challenges and future research agendas*. International Journal of Information Technology and Language Studies, 6(3).
- Alam, A. (2022). *Employing adaptive learning and intelligent tutoring robots for virtual classrooms and smart campuses: Reforming education in the age of artificial*

- intelligence*. In *Advanced computing and intelligent technologies: Proceedings of ICACIT 2022* (pp. 395–406). Springer Nature Singapore.
- Antasari, A., Juniarti, Y., & Lestari, Z. (2025). *Educational transformation in the era of Society 5.0: Challenges and opportunities for educators*. *International Journal of Teaching and Learning*, 3(6), 971–985.
- Babu, B. V. (2024). *Education 5.0: An overview*. In *Advances in technological innovations in higher education* (pp. 168–243).
- Babu, B. V. (2024). *Education 5.0: An overview*. In *Advances in technological innovations in higher education* (pp. 168–243).
- Babu duplicated—kept one version
- Babu, B. V. (2024). *Education 5.0: An overview*. In *Advances in technological innovations in higher education* (pp. 168–243).
- Das, S., Mutsuddi, I., & Ray, N. (2025). *Artificial intelligence in adaptive education: A transformative approach*. In *Advancing adaptive education: Technological innovations for disability support* (pp. 21–50). IGI Global Scientific Publishing.
- Demartini, C. G., Sciascia, L., Bosso, A., & Manuri, F. (2024). *Artificial intelligence bringing improvements to adaptive learning in education: A case study*. *Sustainability*, 16(3), 1347.
- Dermawan, H., & Sumarni, S. (2024). *Basic education in the era of society 5.0: Opportunities and challenges*. *International Journal of Educatio Elementaria and Psychologia*, 1(4), 183–192.
- Dey, S., & Sahoo, B. B. (2025). *AI integration in Education 5.0: Design, challenges, and future prospects*. In *Impacts of AI on Students and Teachers in Education 5.0* (pp. 77–92).
- Eliawati, E., Aprison, W., Maimori, R., Herawati, S., & Putri, Y. M. (2022). *Challenges of society era Education 5.0: Revitalization of teacher competencies and learning models*. *Darussalam: Journal of Psychology and Education*, 1(2), 1–11.
- Er-Rafyq, A., Zankadi, H., & Idrissi, A. (2024). *AI in adaptive learning: Challenges and opportunities*. In *Modern artificial intelligence and data science 2024: Tools, techniques and systems* (pp. 329–342).
- Gowda, R. M. (2023). *Education 5.0: Evolution of promising digital technologies – A comprehensive review*. *International Journal of Advanced Science and Engineering*, 10(2), 3422–3448.
- Guettala, M., Bourekache, S., Kazar, O., & Harous, S. (2024). *Generative artificial intelligence in education: Advancing adaptive and personalized learning*. *Acta Informatica Pragensia*, 13(3), 460–489.
- Gunawan, I. G. D., & Danika, I. W. S. G. (2023). *Leveraging advanced technologies to enhance learning experiences in the Era 5.0*. *International Proceeding on Religion, Culture, Law, Education, and Hindu Studies*, 1, 121–137.
- Hutahaean, B., Telaumbanua, S., Tamba, L., Hutabarat, R. G. N., & Sumani, S. (2024). *Analysis of innovative and adaptive higher education curriculum development to Education 5.0-based challenges in Indonesia*. *International Journal of Learning, Teaching and Educational Research*, 23(4), 76–98.
- Jayanthi, K., Priya, M. S., Saranya, S., Gomathi, R., & Sam, D. (2023). *E-learning as a desirable form of education in the era of Society 5.0*. In *Advances in distance learning in times of pandemic* (pp. 23–51). Chapman and Hall/CRC.
- Judijanto, L., Alfiah, A., & Khusnah, W. D. (2025). *Integration of artificial intelligence and augmented reality in learning in the 5.0 era*. *Jurnal Ilmiah Edukatif*, 11(1), 58–67.
- Masitoh, S. D., & Purbowati, D. (2024). *Enhancing teacher professionalism in Indonesia: Challenges and strategies for digital technology utilization in the Society 5.0 era*. *HEUTAGOGIA: Journal of Islamic Education*, 4(2), 219–236.
- Mobo, F. D. (2024). *Education 5.0: Navigating the future of learning*. In *Preconceptions of Policies, Strategies, and Challenges in Education 5.0* (pp. 268–274). IGI Global.
- Moleka, P. (2023). *Exploring the role of artificial intelligence in Education 6.0: Enhancing personalized learning and adaptive pedagogy*.

- Minh, N. T. T. (2024). *Teacher professional development in Education 5.0*. In *Preconceptions of Policies, Strategies, and Challenges in Education 5.0* (pp. 175–204). IGI Global.
- Pedro, F., Subosa, M., Rivas, A., & Valverde, P. (2019). *Artificial intelligence in education: Challenges and opportunities for sustainable development*.
- Pratyusha, Y. B., & Varghese, B. (2025). *A learner-centered educational landscape: Era of Education 5.0 and disruptive technologies*. In *Mitigating learner disadvantages in teaching and learning* (pp. 159–180). IGI Global Scientific Publishing.
- Rane, N., Choudhary, S., & Rane, J. (2023). *Education 4.0 and 5.0: Integrating artificial intelligence (AI) for personalized and adaptive learning*. SSRN 4638365.
- Rochmat, C. S., Riza, R., & Murni, S. A. (2024). *Artificial intelligence in education: Opportunities and challenges in improving learning efficiency in the Society 5.0 era*. *Progresiva*, 13(01), 91–100.
- Sidik, D. P., Irawijayanti, F., & Baihaqi, A. (2025). *Digital Learning 5.0: Leveraging adaptive, immersive, and inclusive technologies to overcome educational inequity*. *Journal of Innovation in Education and Learning*, 1(2), 75–92.
- Singh, R. (2024). *Navigating Through Education 5.0 Era: Imperative competencies for success*. In *Preconceptions of Policies, Strategies, and Challenges in Education 5.0* (pp. 33–50). IGI Global.
- Supriya, Y., Bhulakshmi, D., Bhattacharya, S., Gadekallu, T. R., Vyas, P., Kaluri, R., ... & Mahmud, M. (2024). *Industry 5.0 in smart education: Concepts, applications, challenges, opportunities, and future directions*. *IEEE Access*, 12, 81938–81967.
- Supa'at, S. A., & Ihsan, I. (2023). *The challenges of elementary education in Society 5.0 era*. *International Journal of Social Learning (IJSL)*, 3(3), 341–360.
- Wu, X., Chong, A. Y. L., Peng, Y., & Bao, H. (2024). *Predicting the acceptance of e-government: A systematic review*. *Internet Research*.
- Zebua, N. (2024). *Optimalisasi potensi dan pemanfaatan artificial intelligence (AI) dalam mendukung pembelajaran di Era Society 5.0*. *Pentagon: Jurnal Matematika dan Ilmu Pengetahuan Alam*, 2(4), 185–195.
- Zohuri, B., & Mossavar-Rahmani, F. (2024). *Revolutionizing education: The dynamic synergy of personalized learning and artificial intelligence*. *International Journal of Advanced Engineering and Management Research*, 9(1), 143–153.