Chatra: Jurnal Pendidikan dan Pengajaran
E-ISSN: 3025-8065 | Page: 196-202
https://journal.yazri.com/index.php/chatra/index

A Literature Analysis of Artificial Intelligence Integration in Adaptive Learning for Secondary Education

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ABSTRACT

The rapid advancement of artificial intelligence (AI) technologies has significantly influenced educational practices, particularly within adaptive learning systems at the secondary level. Although AI has demonstrated substantial potential in personalizing learning processes, its implementation in formal school settings remains constrained by multiple systemic challenges, including educator readiness and infrastructural disparities. This study aims to identify integration patterns of AI in adaptive learning, examine the evolving role of teachers, and explore obstacles and prerequisites for AI adoption in secondary education. Employing a literature review method, this research synthesizes relevant scholarly publications from the past decade and conducts thematic interpretation to uncover current trends in AI utilization. The findings reveal that AI facilitates personalization by adjusting content, pacing, and feedback based on learner profiles, while simultaneously redefining teachers as facilitators of data-driven instruction. Nonetheless, AI adoption continues to be hindered by limited infrastructure, inadequate policy support, and uneven digital competencies among educators. The study concludes that AI integration represents a systemic educational transformation requiring institutional readiness rather than a mere technological add-on. Further empirical research is recommended to validate implementation models across diverse school contexts.

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ARTICLE HISTORY
Received: 23-05-2025
Revised: 16-12-2025
Accepted: 21-12-2025

KEYWORDS
artificial intelligence, adaptive learning, teacher roles, educational transformation

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Introduction

The rapid advancement of Artificial Intelligence (AI) is reshaping educational practices worldwide, particularly within secondary education, where diverse learning needs and cognitive profiles converge. Traditional instructional models, which tend to apply uniform teaching strategies, are increasingly inadequate in addressing the growing demand for learning personalization. AI technologies, by contrast, enable real-time data processing, tailored feedback, and adaptive learning trajectories that align with individual student profiles (Garzón, 2025; Wang et al., 2024). The discrepancy between contemporary pedagogical expectations and existing instructional practices underscores the importance of examining how AI can be meaningfully integrated into adaptive learning at the secondary level.

Recent evidence suggests that AI-powered adaptive learning systems support differentiated instruction, enhance learner autonomy, and provide more precise pedagogical interventions (Ezzaim et al., 2023; Hariyanto et al., 2025). Yet, the success of these innovations is shaped not only by the sophistication of the technology, but also by the readiness of the educational ecosystem—teacher competencies, data governance, and technological infrastructure remain decisive factors for meaningful adoption (Alenezi, 2024; L. Y. Tan et al., 2025). AI integration in education, therefore, must be understood as both a technological and institutional transformation. Over the past decade, interest in AI-driven adaptive learning has grown significantly across the academic community. Studies indicate that AI-based systems have successfully improved learning outcomes, particularly in high-order cognitive subjects such as mathematics and science (Loebis, 2025; S. Tan et al., 2023). Furthermore, machine learning-based personalization frameworks demonstrate how learning pathways can be adapted to align with learners' cognitive characteristics (Lintner, 2024; Rachman, 2025). These developments align with the emerging Education 5.0 paradigm, which positions AI as a foundational element in building future learning ecosystems (Irvan, 2024).

Despite such global advancements, secondary education in Indonesia remains underrepresented in AI research. Issues such as infrastructural disparities, digital literacy gaps among teachers, and the absence of clear data governance policies have not been adequately addressed in existing literature (Kyaw, 2025). This highlights a theoretical and practical gap that warrants a comprehensive examination to integrate global research insights with Indonesia's educational context. To address this gap, the present article provides a structured literature review that synthesizes existing knowledge on AI integration in adaptive learning for secondary education. The study consolidates global research trends, implementation challenges, and policy implications, proposing a conceptual framework that informs future decisions related to AI-enabled pedagogical practices. Rather than merely summarizing findings, this article positions itself as a reference point for aligning AI implementation with Indonesia's educational priorities,

thus contributing to a more equitable, adaptive, and sustainable digital learning ecosystem.

Materials and Methods

This study employed a qualitative research approach using a traditional literature review design to explore the integration of artificial intelligence into adaptive learning at the secondary education level. A literature review was chosen because it enables the researcher to examine, interpret, and synthesize theoretical and empirical insights from existing studies without collecting primary data. This design is appropriate for studies that aim to build conceptual understanding rather than test hypotheses or measure causal relationships (Creswell, 2014). Data were collected from books, journal articles, conference papers, and academic reports obtained through Google Scholar, ScienceDirect, ERIC, and SpringerLink. Unlike systematic literature reviews, this study did not employ rigid inclusion–exclusion criteria; instead, sources were selected based on thematic relevance, scientific credibility, and contribution to the discourse on AI and adaptive learning. Such flexibility reflects the nature of literature-based studies that treat documents as primary data and use them to trace theoretical development and academic debates over time (Zed, 2014).

Data were analyzed using content analysis, which involved identifying key ideas, categorizing concepts, and synthesizing arguments across the reviewed literature. This process requires iterative reading, coding, and interpretation to generate coherent themes and theoretical propositions. The meaning-making procedure followed in this study aligns with the interpretive approach suggested in qualitative data analysis frameworks, ensuring analytical rigor and conceptual clarity (Miles et al., 2014). This research method provides a solid foundation for understanding the pedagogical implications of AI integration in adaptive learning and supports the development of informed perspectives to guide future educational practices.

Result

The results of this literature review were generated from a comprehensive examination of academic publications addressing the integration of artificial intelligence in adaptive learning at the secondary education level. An initial search yielded 54 documents, of which only 15 studies met the predetermined criteria for relevance, clarity of context, and conceptual suitability for secondary school settings. The search process employed combined keywords such as artificial intelligence in education, adaptive learning, personalized instruction with AI, AI-based learning pathways, and secondary students, allowing the review to capture a focused yet varied range of scholarly perspectives. A synthesis of the selected literature indicates that AI functions primarily as a mechanism to personalize learning experiences by aligning instructional content,

feedback processes, and task sequences with individual learner performance. Across the reviewed documents, AI consistently appeared as an autonomous instructional assistant capable of modulating learning pathways to accommodate different levels of student readiness. While the technical features varied among studies, the underlying pattern remained identical: AI transforms learning environments from standardized, teacher-led instruction into personalized, performance-responsive educational systems.

The extracted findings further reveal a shift in the teacher's professional function. Teachers remained integral to instructional processes, yet their responsibilities evolved from transmitting information into interpreting learner data, configuring adaptive instructional responses, and curating learning environments influenced by AI-generated suggestions. Although this transformation was evident in every selected study, the extent of teacher readiness differed across contexts. Moreover, the reviewed literature consistently highlighted structural barriers to AI adoption, including digital infrastructure gaps, financial constraints, and the absence of regulatory mechanisms for data governance in educational settings. Taken together, these findings demonstrate that AI-based adaptive learning is progressing toward practical implementation, though its adoption remains uneven. The success of its integration hinges not solely on technological sophistication but on institutional readiness, teacher competence, and policy alignment. The synthesized evidence confirms that personalized learning mediated by AI is no longer a speculative discourse but a developing educational practice requiring coherent infrastructural support.

Table 1. Summary of Literature-Based Findings on AI-Driven Adaptive Learning

Component of Findings	Summary Output
Selected Articles	15 out of 54 identified in the preliminary search
Period of Publication	2015–2025
Research Databases	Google Scholar, ERIC, ScienceDirect, SpringerLink
Search Keywords	*AI in education*, *adaptive learning*, *secondary level*, *AI-driven personalization*
Primary Learning Focus	Automated content sequencing, performance-based pacing, personalized feedback
Teacher's Role	Facilitator, data interpreter, instructional strategist
Barriers to Implementation	Unequal infrastructure, insufficient digital literacy, cost, absence of supporting policy
Direct Implications	Learning trajectories vary based on individual student learning profiles

Discussion

The findings of this study demonstrate that the integration of artificial intelligence (AI) into adaptive learning environments represents a significant pedagogical departure from conventional instructional models. The capacity of AI to calibrate content difficulty, learning sequences, and feedback based on individual student performance reinforces the premise that adaptive learning systems hold substantial promise for personalized instruction. This observation aligns with Wang et al., (2024), who argue that AI-based learning pathways enable real-time personalization grounded in ongoing learner data. Such alignment indicates that AI is not merely a technological augmentation; rather, it reshapes educational logic by positioning student characteristics as the primary determinant of instructional flow, thereby fulfilling the study's objective of identifying the structural pattern of AI integration in secondary education.

The transformation of the teacher's role uncovered in this review further underscores the systemic implications of AI adoption. Whereas traditional pedagogy situates teachers as central transmitters of knowledge, the adaptive learning context assigns them a more interpretive and facilitative role. Garzón, (2025) emphasizes that AI does not replace educators; instead, it redirects their responsibilities toward analyzing system-generated data and making informed pedagogical decisions. This assertion is reinforced by Hariyanto et al., (2025), who highlights that teacher expertise in interpreting learning analytics becomes crucial for tailoring interventions. The present study expands these insights by revealing that AI integration necessitates pedagogical, digital, and data-interpretive competencies, thereby elevating the professional expectations placed on educators in technology-mediated learning environments.

The structural constraints identified in this review reveal that successful AI implementation extends beyond issues of technical sophistication. The analysis highlights infrastructural inequalities, financial limitations, and inconsistent policy provisions as central impediments to AI adoption in secondary schools. This finding is consistent with Alenezi (2024), who notes that the efficacy of AI depends not solely on the system's capabilities but on the readiness of the educational ecosystem. Loebis, (2025) similarly identifies digital access disparities in Asian schools as a key barrier that often undermines the transformative aims of AI initiative. Taken together, these converging perspectives demonstrate that AI cannot be conceptualized as a context-neutral innovation; its effectiveness is contingent upon a set of social, institutional, and material conditions.

Beyond confirming these challenges, the present study contributes a theoretical extension to existing discourse by identifying the curricular implications of AI integration. Rachman, (2025) argues that machine-learning algorithms enable curriculum personalization, and this review corroborates that claim while emphasizing that personalization requires more than algorithmic precision. It also necessitates coherent

data-governance policies, institutional support mechanisms, and teacher capacity development. In parallel, Irvan, (2024) situates AI within the broader paradigm of Education 5.0, asserting that AI must be conceptualized not merely as a digital tool but as a structural element that redefines the educational ecosystem. This study reinforces that assertion, demonstrating that AI introduces both pedagogical opportunities and institutional dependencies that demand coordinated system-level responses.

Notwithstanding its contributions, this study recognizes inherent limitations stemming from its literature-based nature. Because the review synthesizes conceptual and empirical insights without conducting field validation, its conclusions remain interpretive rather than causal. This limitation echoes concerns raised by Tan et al., (2023), who note that claims about AI effectiveness require empirical substantiation in authentic classroom settings. Furthermore, the reliance on accessible digital databases suggests that relevant studies published outside mainstream indexing may not have been captured, leaving open the possibility of unexamined perspectives or contradictory evidence. These constraints underscore that the present findings serve as an analytical map rather than a definitive assessment of AI's operational impact.

In light of these limitations, future research is recommended to adopt empirical methods that directly examine AI-supported adaptive learning in diverse Indonesian school contexts. Kyaw, (2025) proposes staged implementation models in developing environments, advocating for pilot institutions as testing grounds for technologically mediated reforms. This study concurs and recommends multi-level initiatives that include teacher training, infrastructure enhancement, and policy frameworks governing data usage and system interoperability. Such an approach will ensure that AI evolves not as a speculative ideal but as a transformative and equitable educational instrument capable of strengthening national learning outcomes and preparing students for future digital competencies.

Conclusion

This study concludes that the integration of artificial intelligence into adaptive learning at the secondary education level holds substantial potential to transform instructional practices from standardized approaches into systems that respond to individual learner needs. The findings indicate that AI enables dynamic adjustments to content, pacing, and feedback based on student performance, while simultaneously redefining the teacher's role as a facilitator of data-driven learning. Furthermore, the success of AI implementation is contingent upon ecosystem readiness, including infrastructure, teacher competence, and supportive policy frameworks. Accordingly, this research not only fulfills its objective of identifying integration patterns and associated challenges, but also contributes theoretically by demonstrating that educational technologies constitute systemic reforms rather than isolated tools. Future studies are

recommended to empirically examine AI-based adaptive learning models across diverse school contexts to reinforce theoretical insights and broaden practical implementation strategies.

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