



Artificial Intelligence Supported Personalized Learning: Examining Its Impact on Students' Critical Thinking, Learning Engagement, and Academic Achievement in Higher Education

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Abstract

Artificial intelligence (AI)-supported personalized learning provides adaptive instructional content, individualized feedback, and differentiated learning pathways, although its educational outcomes remain inconsistently established. This study examines the relationships between AI-supported personalized learning and students' critical thinking, learning engagement, and academic achievement in higher education. A structured integrative literature review was conducted using 24 scholarly publications from 2022–2026. Qualitative thematic synthesis examined technological mechanisms, reported educational outcomes, and pedagogical conditions while distinguishing empirical findings from conceptual interpretations. The findings identify adaptive questioning, reflective feedback, and individualized cognitive challenges as potential mechanisms supporting critical thinking, although direct evidence of measurable improvement remains limited. Personalized instructional support is associated with learning engagement through relevance, motivation, and sustained participation, while adaptive assessment, individualized feedback, and self-regulated learning are linked to reported academic achievement. These relationships vary according to instructional design, learner autonomy, digital competence, and educational context. The reviewed evidence does not establish causal relationships among the three outcomes. The bounded literature corpus, heterogeneous research designs, and absence of a standardized quality appraisal limit generalizability. The review contributes an integrated interpretation distinguishing reported educational associations from proposed mechanisms and identifies priorities for longitudinal, comparative, and outcome-specific empirical investigation.

Keywords: Academic Achievement, Artificial Intelligence, Critical Thinking, Higher Education, Personalized Learning.



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INTRODUCTION

Artificial intelligence (AI) has become an increasingly prominent component of higher education through technologies that adapt instructional content, generate individualized feedback, analyse learner performance, and support differentiated learning pathways. AI-supported personalized learning encompasses adaptive learning systems, intelligent tutoring, learning analytics, recommendation technologies, and AI-enabled assessment, although these applications differ considerably in their instructional functions and underlying mechanisms (Peng & Li, 2025). Their growing adoption reflects the need to accommodate differences in students' prior knowledge, learning pace, academic preparation, and instructional requirements. A systematic review of adaptive education identifies multiple computational approaches to personalization, ranging from performance-based content adjustment to individualized assessment and learning-pathway recommendations (Hariyanto et al., 2025). Evidence concerning adaptive learning systems also suggests potential improvements in student engagement when instructional activities respond to individual learning conditions (Hidayat et al., 2025). Nevertheless, technological responsiveness should not be equated with educational effectiveness because greater interaction with adaptive systems does not necessarily indicate stronger conceptual understanding, independent reasoning, or academic achievement. Evaluating AI-supported

personalized learning therefore requires distinguishing the instructional functions provided by AI from the cognitive, behavioural, and academic outcomes associated with their implementation.

Existing systematic reviews provide important but differently focused accounts of AI-supported learning in higher education. Peng and Li (2025) examine developments in AI technologies for personalized learning, while Hariyanto et al. (2025) focus on adaptive educational techniques and their personalization functions. Merino-Campos (2025) addresses the broader application of AI-supported personalized learning in higher education, placing greater emphasis on its educational implications. Other reviews concentrate on particular outcome domains: Adewale (2026) examines personalization in relation to student engagement and motivation, Long et al. (2026) consider student engagement alongside the role of teaching methods, and Sriwahyuni (2026) focuses specifically on critical thinking within AI-supported personalized learning. Naseer et al. (2026) extend the discussion to teaching effectiveness, student engagement, and learning outcomes through a systematic qualitative review of AI-powered educational tools. These contributions differ in their principal research questions, technological scope, and outcome emphasis, although their precise methodological comparability requires examination of their respective search procedures, inclusion criteria, and analytical approaches. Their combined coverage provides a basis for examining the three educational outcomes together, but it does not itself establish how changes in critical thinking, engagement, and academic achievement are related. The remaining analytical problem concerns the extent to which the available evidence supports each outcome directly, whether the same personalization mechanisms operate across different outcomes, and which proposed relationships remain conceptual rather than empirically demonstrated.

Critical thinking represents a particularly demanding criterion for evaluating the educational value of AI personalization because it requires students to interpret information, assess competing claims, formulate arguments, and exercise independent judgment. Bolarinwa (2026) associates AI-supported learning with cognitive development and critical thinking, while Faizi et al. (2026) report relationships between AI-assisted learning, academic performance, and critical thinking among undergraduate students. These findings are relevant to the present review, but AI-assisted learning and AI-supported personalized learning should not be treated as equivalent constructs. General AI assistance may provide explanations or generated responses without systematically adapting instructional activities to individual learning needs, whereas personalized learning involves some form of learner-specific instructional adjustment. Research on adaptive assessment indicates that AI can connect learner responses with differentiated evaluation and subsequent instructional support, although this functionality does not independently demonstrate improvement in higher-order reasoning (Anuyahong et al., 2023). Similarly, AI-enabled intelligent assistants can provide responsive guidance and individualized interaction, but their capacity to support critical thinking depends on the cognitive demands imposed on students (Sajja et al., 2024). The human–AI collaboration framework advanced by Palappetty (2026) offers a conceptual explanation for this distinction by positioning AI as a resource for questioning, reflection, and argument evaluation rather than a substitute for independent reasoning. The evidence consequently requires interpretation according to whether critical thinking was directly measured, inferred from academic performance, or proposed as a potential consequence of particular instructional mechanisms.

Learning engagement and academic achievement constitute related but analytically distinct dimensions of AI-supported personalized learning. AI-based learning analytics can identify patterns in student performance and interaction, enabling instructional responses that are more closely aligned with individual learning requirements (Alifah & Hidayat, 2025). Such responsiveness may support behavioural participation, motivational persistence, and cognitive engagement, but these dimensions cannot be inferred solely from the frequency of platform use or interaction with AI-generated content. Research on personalized AI learning associates individualized instructional support with student motivation and academic performance, although the reported relationships must be interpreted in relation to the measures and research designs employed (Imran et al., 2025). Formative assessment research similarly connects AI integration with engagement, learning approaches, and educational outcomes, indicating that the instructional role of assessment is relevant to interpreting reported benefits (Pratiwi et al., 2026). Evidence concerning AI-enhanced personalized learning also identifies potential improvements in students' learning experiences through differentiated instructional support (Iman et al., 2024). Hassan (2026) further examines AI in relation to engagement and academic performance, extending the evidence beyond technological adaptation toward educational outcomes. Nevertheless,

engagement and achievement remain different constructs: increased participation does not automatically establish improved academic attainment, and higher assessment scores do not necessarily demonstrate deeper understanding or critical reasoning. Their relationship therefore requires examination through the reported evidence rather than through assumptions that improvements in one dimension necessarily produce improvements in another.

The interpretation of these outcomes is further complicated by differences in instructional contexts, learner characteristics, and the implementation of AI-supported technologies. Reviews of AI integration identify challenges involving technological infrastructure, personalization quality, usability, and the institutional conditions required to incorporate AI into educational practice (Miranda, 2025). Research on academic performance also indicates that self-regulated learning, motivation, and digital literacy may influence relationships between AI use and educational outcomes, suggesting that student characteristics should not be separated from the instructional technologies being evaluated (Arifin, 2026). Equity considerations introduce an additional distinction because personalization may improve access to appropriately differentiated learning opportunities without necessarily reducing existing inequalities in digital competence or technological resources (Feng et al., 2025). These factors limit the generalizability of positive findings across institutions, disciplines, learner populations, and educational settings. They also expose an evidentiary problem in studies that describe the potential advantages of personalization without distinguishing technological capabilities, measured student outcomes, and the contextual conditions under which those outcomes were observed. Although previous scholarship establishes the relevance of AI personalization to several educational dimensions, a more differentiated synthesis is needed to assess the nature and strength of the reported evidence across critical thinking, engagement, and academic achievement. The contribution of an integrated review therefore lies in comparing these outcome domains and identifying their shared instructional mechanisms and evidentiary limitations, rather than presuming that the available literature establishes a unified causal process.

The present review examines AI-supported personalized learning in higher education through an integrated analysis of critical thinking, learning engagement, and academic achievement. Four research questions guide the synthesis. The first asks what evidence supports an association between AI-supported personalized learning and students' critical thinking, particularly when critical-thinking performance is distinguished from theoretically proposed cognitive benefits. The second examines how personalization mechanisms relate to behavioural, cognitive, and motivational dimensions of learning engagement. The third investigates the evidence concerning academic achievement and the instructional or learner-related conditions associated with reported outcomes. The fourth considers which personalization mechanisms and pedagogical conditions are common across the three outcome domains and whether the available studies support relationships among these outcomes. By differentiating empirical findings, evidence reported in previous reviews, and conceptual explanations, the analysis addresses the limitations of interpretations that treat technological functionality as direct evidence of educational improvement. Its contribution is an outcome-oriented thematic synthesis that identifies areas of convergence, differences in evidentiary support, and unresolved relationships requiring direct empirical investigation. The objective is to establish what the available scholarship permits researchers to conclude about AI-supported personalization without attributing causal effects that the reviewed evidence cannot substantiate.

RESEARCH METHODS

This study employed a structured integrative literature review supported by qualitative thematic synthesis to examine AI-supported personalized learning and its relationship with critical thinking, learning engagement, and academic achievement in higher education. The analytical corpus comprised 24 scholarly publications published between 2022 and 2026 and documented in the manuscript's reference list. The sources included empirical investigations, systematic and qualitative reviews, conceptual scholarship, and research addressing educational applications of artificial intelligence. The analytical scope covered adaptive learning systems, intelligent tutoring, AI-based learning analytics, personalized feedback, intelligent educational assistants, and AI-supported assessment. Four substantive criteria guided the selection and organization of relevant literature: a higher education context, an explicit connection with artificial intelligence, substantive relevance to personalized or adaptive learning, and consideration of at least one of the three focal educational outcomes. Publications

examining AI-assisted learning more generally were retained for contextual comparison where relevant but were distinguished from investigations specifically addressing personalized learning mechanisms. The emphasis on contemporary publications reflects the changing technological characteristics and educational applications of AI-supported personalization (Peng & Li, 2025). The scope also incorporated research examining engagement and motivation (Adewale, 2026) and studies addressing critical thinking as a separate dimension of higher-order learning (Sriwahyuni, 2026). Because the documented review materials do not establish a reproducible database-specific search and screening history, the investigation is classified as a structured integrative review rather than a comprehensive systematic review conducted under a formally documented bibliographic screening protocol.

The literature was examined through a thematic synthesis procedure involving source classification, identification of relevant findings, thematic coding, comparison, and interpretative integration. The first analytical category concerned critical thinking, with attention to reasoning, analysis, evaluation, problem solving, reflective judgment, and independent intellectual engagement. The second category concerned learning engagement, incorporating behavioural participation, cognitive involvement, motivation, persistence, and interaction with instructional activities. The third category addressed academic achievement through reported learning outcomes, academic performance, assessment results, and achievement-related indicators. Information concerning technological mechanisms was examined alongside these categories to determine how adaptive content, individualized feedback, learning analytics, intelligent assistance, formative assessment, and personalized learning pathways were represented in the literature. The relevance of AI-enabled intelligent assistance was considered in relation to its potential capacity to provide differentiated learning support rather than as independent evidence of improved cognitive performance (Sajja et al., 2024). The synthesis distinguished empirical findings reported by individual investigations from conclusions presented in previous research reviews and mechanisms proposed through conceptual analysis. This distinction was necessary because evidence concerning AI-supported engagement and learning outcomes varies according to teaching methods and educational contexts (Long et al., 2026). Comparisons across the three categories focused on recurring findings, differences in outcome interpretation, and conditions that could explain variation among the reviewed publications.

The analytical procedure emphasized the relationship between reported findings and their supporting evidence rather than the frequency of favourable conclusions. Claims concerning educational improvement were interpreted with reference to the type of research presented, the outcome investigated, and the extent to which the reported observations directly concerned AI-supported personalization. Conceptual descriptions of technological functions were not treated as equivalent to empirical demonstrations of educational effectiveness, and associations reported in the literature were not interpreted as established causal effects. Particular attention was given to the distinction between AI applications that provide instructional adaptation and systems that primarily generate information or assist students without individualized adjustment. The synthesis also considered reported implementation constraints involving digital competence, technological infrastructure, teaching practices, and institutional conditions because these factors may influence the educational relevance of personalized AI technologies (Miranda, 2025). Findings from primary investigations, previous reviews, and conceptual publications were integrated qualitatively without calculating pooled effect sizes or assigning a quantitative estimate of intervention effectiveness. A standardized study-level risk-of-bias assessment was not incorporated into the documented review procedure, limiting the extent to which the relative strength of individual findings could be determined. The resulting analysis therefore provides a structured interpretation of the cited scholarship rather than an exhaustive estimate of the effectiveness of AI-supported personalized learning across higher education institutions.

RESULTS AND DISCUSSION

AI-Supported Personalized Learning and Its Influence on Critical Thinking

The thematic synthesis indicates that AI-supported personalized learning has increasingly been conceptualized as a learning environment capable of adapting instructional content, assessment, feedback, and learning pathways to individual learner characteristics rather than merely automating conventional teaching tasks. Across the reviewed literature, personalization is primarily enabled through adaptive algorithms, learning analytics, intelligent assistants, and AI-mediated assessment that use information about learner performance and behaviour to modify subsequent learning experiences.

This technological architecture is important for critical thinking because individualized learning can provide students with tasks and feedback that are more closely aligned with their existing knowledge and cognitive needs. A systematic review of AI personalization in higher education identifies adaptive systems as particularly significant because they can dynamically adjust learning resources and pathways according to learner profiles and performance (Hariyanto et al., 2025). The analytical evidence suggests that the potential cognitive value of personalization emerges when adaptation creates opportunities for students to confront progressively more complex problems rather than simply receiving easier or faster access to information. Such an orientation shifts personalized learning from an efficiency-oriented model toward a developmental model in which AI functions as a scaffold for higher-order cognitive activity.

The reviewed studies identify several mechanisms linking AI-supported personalization with critical thinking, particularly individualized questioning, adaptive problem solving, differentiated learning materials, and feedback that directs students toward reflection and evaluation. These mechanisms are theoretically relevant because critical thinking develops through repeated engagement with information that requires comparison, interpretation, justification, and judgment rather than through information acquisition alone. The evidence synthesized from the literature can be organized according to the principal AI mechanisms and their potential cognitive functions, as presented in Table 1.

Table 1. AI-Supported Personalized Learning Mechanisms Relevant to Critical Thinking

Ai-Supported Mechanism	Personalization Function	Cognitive Function Relevant to Critical Thinking	Educational Implication
Adaptive Learning Systems	Adjust content and difficulty according to learner performance	Progressive reasoning and problem solving	Students can encounter tasks aligned with their developing cognitive capacity
Learning Analytics	Identify patterns in learner performance and behaviour	Recognition of weaknesses and self-monitoring	Learning decisions can become more evidence-informed
Intelligent Assistants	Provide individualized interaction and guidance	Inquiry, explanation, and reflective reasoning	Students can receive responsive cognitive support
Adaptive Assessment	Modify assessment according to learner responses	Evaluation and application of knowledge	Assessment can become part of the learning process
AI-Generated Feedback	Provide targeted responses to learner work	Revision, reflection, and error evaluation	Students can reconsider and improve their reasoning
Personalized Learning Pathways	Sequence learning according to individual progress	Independent decision-making and problem solving	Learners can engage with differentiated cognitive demands

Table 1 indicates that the cognitive contribution of AI does not reside in personalization itself but in the learning activities that personalization makes possible. Intelligent assistants, for example, can create interactive opportunities for students to request clarification, test interpretations, and examine alternative explanations, although the educational value of these interactions depends on whether students remain responsible for evaluating the information provided by the system. Research on AI-enabled intelligent assistants supports the feasibility of combining personalization and adaptive learning in higher education, particularly through individualized support and responsive interaction (Sajja et al., 2024). The literature therefore supports an interpretation of AI as a potential cognitive scaffold rather than an independent producer of critical thinking. When students are required to interrogate AI-generated information, compare competing explanations, and justify their conclusions, personalization may increase the relevance of cognitive tasks while preserving the intellectual work performed by the

learner. This distinction is central to interpreting the reported relationship between AI-supported learning and critical thinking because a personalized environment can either stimulate higher-order reasoning or reduce it, depending on how the technology structures students' engagement with knowledge.

Evidence concerning the relationship between AI-supported learning and critical thinking generally reports a positive association, although the strength of that relationship is conditioned by the pedagogical role assigned to AI within the learning process. Research examining AI-assisted learning among undergraduate students reports improvements in critical thinking alongside academic performance, indicating that AI-supported instructional environments are associated with cognitive benefits when integrated into students' learning activities (Faizi et al., 2026). A broader analysis of AI and students' academic development similarly associates AI-supported learning with critical thinking and cognitive skills, suggesting that the technology can contribute to higher-order learning when its functions extend beyond routine information delivery (Bolarinwa, 2026). Table 2 summarizes the principal patterns identified across the literature concerning the relationship between AI-supported personalized learning and critical thinking.

Table 2. Literature-Based Synthesis of AI-Supported Learning and Critical Thinking

Study	AI/Personalization Focus	Critical Thinking Relevance	Main Analytical Implication
Bolarinwa (2026)	AI-supported learning and academic development	Critical thinking and cognitive skills	AI-supported learning is associated with higher-order cognitive development
Faizi et al. (2026)	AI-assisted learning among undergraduates	Critical thinking and academic performance	AI-assisted learning is associated with cognitive and academic improvement
Sriwahyuni (2026)	AI-supported personalized learning	Critical thinking development	Personalization can support critical thinking when learning remains cognitively active
Palappetty (2026)	Human–AI collaboration	Critical thinking and academic performance	AI is more productive as a collaborative cognitive resource than a replacement for reasoning
Sajja et al. (2024)	Intelligent assistant for adaptive learning	Personalized cognitive support	Interactive AI can provide individualized learning assistance
Anuyahong et al. (2023)	Personalized learning and adaptive assessment	Evaluation and adaptive learning	AI-supported assessment can connect learner responses with individualized learning pathways

The evidence in Table 2 reveals a consistent conceptual pattern: positive cognitive outcomes are more plausibly associated with active human–AI interaction than with technological personalization considered independently. Sriwahyuni's systematic review emphasizes that AI-supported personalized learning can enhance critical thinking when students remain actively involved in analysing and evaluating information rather than accepting AI outputs without scrutiny (Sriwahyuni, 2026). This finding is compatible with a human–AI collaboration perspective in which AI supplies prompts, alternative perspectives, feedback, or informational resources while students retain responsibility for interpretation and judgment (Palappetty, 2026). Such an arrangement can create a productive form of cognitive scaffolding because the system responds to individual needs while the learner continues to perform the evaluative processes that constitute critical thinking. The literature also suggests that adaptive assessment can reinforce this process by generating information about students' responses that can be used to tailor subsequent learning experiences (Anuyahong et al., 2023). Critical thinking therefore appears to be influenced not simply by the availability of AI-generated assistance but by the

extent to which personalized learning environments transform that assistance into opportunities for questioning, comparison, reasoning, and reflection. The analytical implication is that AI personalization should be evaluated according to the quality of cognitive activity it elicits, rather than according to the sophistication of the underlying technology alone.

A further finding concerns the tension between personalization and cognitive autonomy, which becomes particularly important when AI systems provide highly immediate and individualized answers to students' questions. Excessive automation can reduce the need for learners to formulate explanations independently, assess competing evidence, or tolerate uncertainty during problem solving, creating a potential form of cognitive offloading that may conflict with the developmental aims of higher education. The literature on AI-supported critical thinking therefore points toward a conditional relationship in which AI produces greater cognitive value when students are encouraged to verify, challenge, and extend AI-mediated information rather than treating it as an authoritative solution (Sriwahyuni, 2026). This concern does not negate the educational potential of personalization; instead, it indicates that personalization should be accompanied by instructional structures that explicitly preserve learner agency and intellectual responsibility. From this perspective, AI-supported personalized learning can be understood as a mediated cognitive environment in which adaptive technology modifies the conditions of learning while students remain the primary agents of interpretation and judgment. The findings position critical thinking as an outcome that depends on the interaction between technological adaptation and pedagogical design rather than on AI implementation in isolation. This interpretation provides a basis for examining whether the same personalization mechanisms that support cognitive engagement also contribute to students' broader learning engagement and academic achievement.

AI-Supported Personalized Learning and Student Learning Engagement

The reviewed literature consistently associates AI-supported personalized learning with changes in student engagement when instructional experiences are made more responsive to individual learning characteristics, progress, and preferences. Unlike conventional digital learning environments that primarily provide uniform materials, adaptive AI systems can modify content, task difficulty, feedback, and learning sequences according to students' interactions with the learning environment. This responsiveness is particularly relevant to engagement because students are more likely to sustain participation when learning activities are perceived as relevant to their current abilities and learning needs. Research on AI-based personalized learning indicates that adaptive systems can strengthen student engagement by providing individualized learning experiences and more responsive instructional support (Hidayat et al., 2025). Engagement in this context should not be reduced to frequency of platform use because meaningful engagement also involves cognitive investment, persistence, motivation, and active participation in learning processes. The literature therefore suggests that the principal contribution of AI personalization is not simply increasing the amount of student interaction with technology, but potentially improving the quality and continuity of students' interaction with learning tasks.

The synthesis identifies several mechanisms through which AI-supported personalization can influence engagement, particularly adaptive content delivery, individualized feedback, learning analytics, intelligent assistance, and personalized learning pathways. These mechanisms can reduce the mismatch between students' learning needs and standardized instructional materials by enabling learning activities to respond to differences in prior knowledge, progress, and interaction patterns. Learning analytics is particularly important because the information generated from students' activities can be transformed into personalized recommendations and instructional responses rather than remaining merely as records of academic behaviour. Evidence concerning AI-based learning analytics indicates that such tools can support personalized learning by using learner information to facilitate more targeted educational interventions (Alifah & Hidayat, 2025). The main engagement-related mechanisms identified in the reviewed literature are summarized in Table 3.

Table 3. AI Personalization Mechanisms Associated with Student Learning Engagement

Ai Personalization Mechanism	Engagement Dimension		Synthesized Contribution	Key Educational Function
Adaptive Content	Cognitive behavioural	and	Greater relevance of learning tasks	Adjusts materials to learner progress
Personalized Feedback	Cognitive motivational	and	Sustained effort and reflection	Provides timely information about learning performance
Learning Analytics	Behavioural cognitive	and	Early identification of disengagement	Uses learner data to inform instructional responses
Intelligent Assistants	Behavioural cognitive	and	Continuous interaction and support	Provides individualized assistance during learning
Adaptive Assessment	Cognitive motivational	and	Greater participation in evaluation	Aligns assessment with learner development
Personalized Pathways	Behavioural motivational	and	Persistence and learning continuity	Adjusts sequencing according to individual progress

Table 3 indicates that engagement is produced through a combination of technological responsiveness and pedagogical relevance rather than through AI functionality alone. Adaptive content can make learning tasks more accessible or appropriately challenging, while personalized feedback can provide students with information that supports persistence and encourages them to reconsider their performance. Research examining AI in personalized learning similarly identifies personalization as a mechanism for strengthening student engagement when adaptive systems respond to individual learning patterns (Iman et al., 2024). The distinction between technological interaction and educational engagement remains important because students may interact frequently with an AI system without demonstrating sustained cognitive involvement in the learning process. A meaningful increase in engagement requires students to invest attention, effort, and reflection in educational tasks, making the design of AI-mediated activities a decisive factor in determining whether personalization produces substantive engagement. The literature therefore supports a multidimensional understanding of engagement in which AI personalization can influence behavioural participation while also potentially strengthening cognitive and motivational involvement.

The relationship between AI and engagement is also closely connected with motivation because personalized learning can reduce perceived instructional irrelevance and provide students with learning experiences that correspond more closely to their individual needs. Recent systematic evidence indicates that AI-supported personalization is associated with student engagement and motivation, while also emphasizing that the quality of implementation influences whether these benefits are realized (Adewale, 2026). Personalized systems may contribute to motivation by providing achievable but progressively challenging tasks, immediate feedback, and learning pathways that allow students to perceive greater control over their learning processes. Such mechanisms can strengthen persistence because students receive instructional responses that are more closely aligned with their current performance rather than being required to progress through identical activities regardless of individual differences. Manaf and Mufid (2026) similarly emphasize the relevance of AI integration in adaptive learning for understanding students' personalized learning experiences in digital educational environments. These findings indicate that personalization may strengthen engagement when students perceive AI as responsive support rather than as an external monitoring mechanism. The motivational dimension is consequently important because sustained engagement depends not only on whether AI adapts learning but also on whether students perceive that adaptation as useful, meaningful, and supportive of their own learning agency.

The reviewed literature also reveals that the relationship between AI personalization and engagement is mediated by instructional context, particularly the teaching methods through which AI-supported activities are incorporated into higher education. A systematic review of AI in higher

education identifies teaching methods as an important factor shaping the relationship between AI implementation and student engagement, indicating that technological availability does not automatically produce stronger participation (Long et al., 2026). This finding challenges technology-centred assumptions that adaptive systems inherently create engaging learning environments because students' responses remain influenced by instructional structure, teacher facilitation, task design, and opportunities for interaction. Research examining AI-powered tools similarly reports potential improvements in student engagement and learning outcomes while emphasizing the importance of how AI is integrated into teaching practices (Naseer et al., 2026). Engagement is therefore better interpreted as an outcome emerging from the interaction among AI responsiveness, pedagogical design, and student agency. An AI system may provide personalized recommendations, yet students still require meaningful learning tasks that encourage them to apply, discuss, evaluate, and extend the information provided. This relationship places instructors in an important mediating position because effective AI-supported personalization does not eliminate teaching but changes how educators organize and respond to individualized learning processes.

The synthesis further indicates that AI-supported personalization has implications for educational equity because adaptive learning can potentially accommodate differences among students that standardized instructional approaches may overlook. Personalization can provide differentiated pathways for learners with different levels of prior knowledge, learning pace, and engagement patterns, creating opportunities for students to participate through learning experiences more closely aligned with their individual circumstances. Feng et al. (2025) conceptualize AI-driven personalization as a mechanism with potential implications for both educational equity and engagement because adaptive systems can respond to learner diversity rather than assuming uniform educational needs. This potential, however, should not be interpreted as evidence that AI automatically resolves inequalities because differences in digital literacy, access to technology, institutional support, and students' capacity to use AI critically can shape the benefits they receive. The reviewed evidence consequently supports an interpretation of AI personalization as a conditional resource for engagement whose effectiveness depends on the interaction between technological adaptability, pedagogical support, and learner characteristics. Engagement becomes most educationally meaningful when adaptive technologies encourage sustained participation while simultaneously preserving cognitive agency and purposeful interaction with academic content. This interpretation establishes an important connection with the next outcome domain, academic achievement, because increased engagement becomes educationally consequential only when it contributes to deeper learning and measurable academic development.

AI-Supported Personalized Learning and Academic Achievement

AI-supported personalized learning presents academic achievement as an outcome emerging from the interaction between individualized instruction, learner responsiveness, feedback, and students' capacity to regulate their own learning processes. The literature indicates that AI can contribute to academic performance by adapting learning materials and activities to students' demonstrated levels of understanding, potentially reducing the mismatch between instructional difficulty and individual learning needs. Personalized systems can also provide timely feedback that enables students to identify weaknesses and modify their learning strategies before misconceptions become persistent. Evidence on AI-supported personalized learning reports positive associations between individualized learning and academic performance, particularly when personalization is accompanied by motivational and instructional support (Imran et al., 2025). Academic achievement should not be interpreted as a direct technological effect because learning outcomes remain dependent on how students interact with adaptive environments and how AI-generated support is incorporated into instructional practices. The evidence positions AI-supported personalization as a potential mechanism for strengthening academic achievement through more responsive learning processes rather than as an autonomous determinant of student performance.

The literature identifies several pathways linking AI-supported personalization with academic achievement, including adaptive content, individualized feedback, learning analytics, adaptive assessment, personalized recommendations, and intelligent academic assistance. These mechanisms enable educational systems to respond to differences in students' knowledge, progress, and learning behaviour while providing targeted resources for addressing identified weaknesses. Learning analytics is particularly relevant because student performance data can be transformed into individualized

recommendations and interventions that help learners and educators make more informed decisions about subsequent learning activities. Evidence on AI-based learning analytics demonstrates its potential to support personalized learning by identifying learner characteristics and performance patterns that can inform targeted educational responses (Alifah & Hidayat, 2025). The principal mechanisms and their synthesized contributions to academic achievement are presented in Table 5.

Table 5. AI-Supported Personalization Mechanisms and Academic Achievement

Ai-Supported Mechanism	Academic Function	Synthesized Contribution to Achievement	Key Condition
Adaptive Content	Matches material with learner performance	Improved mastery of academic content	Accurate identification of learning needs
Personalized Feedback	Identifies errors and guides revision	Improved performance through corrective learning	Feedback must be timely and actionable
Learning Analytics	Monitors learner progress	Targeted intervention and support	Reliable learner data
Adaptive Assessment	Adjusts assessment according to responses	Better alignment between assessment and learning	Appropriate assessment design
Personalized Recommendations	Directs learners toward relevant resources	More efficient use of learning time	Relevance of recommendations
Intelligent Assistance	Provides individualized academic support	Continuous clarification and problem solving	Active student participation

Table 5 indicates that academic benefits arise from the combination of several adaptive mechanisms rather than from AI functionality in isolation. Adaptive content can align instructional difficulty with learner readiness, while personalized feedback can help students identify errors and undertake corrective learning. AI-supported assessment is particularly significant because assessment can function as an instructional process that generates information for subsequent learning rather than simply producing a final score. Research on AI-supported assessment and feedback highlights the capacity of intelligent systems to provide more responsive information that can support student success in higher education (Hooda et al., 2022). The academic value of these mechanisms depends on whether students transform AI-generated information into deliberate learning actions instead of merely receiving automated recommendations. Personalized learning becomes academically consequential when adaptive information contributes to a continuing cycle of diagnosis, feedback, learner response, and instructional adjustment. This process provides a stronger explanation for academic improvement than the assumption that AI adoption alone automatically produces higher achievement.

The relationship between AI-supported personalization and academic achievement becomes more complex when learner characteristics such as self-regulated learning, motivation, and digital literacy are considered. AI can provide highly individualized resources, but students still require the capacity to interpret recommendations, manage learning activities, evaluate feedback, and determine how technological assistance should be incorporated into their study practices. Research examining AI and academic performance identifies self-regulated learning as an important mediating mechanism while highlighting the influence of learning motivation and digital literacy on students' academic outcomes (Arifin, 2026). This evidence challenges a purely technology-centred interpretation of personalized learning because the same AI-supported environment may produce different academic consequences depending on students' ability to use technological resources strategically. Students who monitor their progress and actively respond to AI-generated feedback may obtain greater educational value than students who depend on AI to complete learning tasks without independent cognitive processing. Academic achievement can therefore be understood as an outcome of interaction between technological affordances and learner agency. The effectiveness of AI personalization depends not only

on how accurately a system adapts learning but also on whether students possess the capacity and motivation to act upon that adaptation.

The synthesis further indicates that academic achievement is closely connected with the quality of engagement generated by personalized learning environments. AI-supported personalization can increase access to relevant materials, individualized explanations, and adaptive assistance, yet these resources become educationally meaningful only when students remain actively involved in learning activities. Evidence concerning AI-powered personalized learning systems indicates positive relationships between personalization, student performance, and engagement, suggesting that these outcomes can develop together when AI is integrated into learning processes rather than used as an isolated technological tool (Saleem et al., 2025). This relationship suggests that engagement may constitute an important pathway through which personalization contributes to achievement because sustained participation provides greater opportunities for students to process information, apply feedback, and consolidate knowledge. The relationship should not be interpreted as automatically linear because frequent interaction with an AI platform does not necessarily indicate conceptual understanding or meaningful academic development. Personalized systems can facilitate learning efficiency, but achievement remains dependent on the depth of students' cognitive processing and their willingness to engage with demanding academic tasks. The academic contribution of AI personalization is therefore strongest when individualized technological support reinforces active participation rather than replacing students' learning efforts.

The reviewed evidence also highlights a distinction between immediate performance improvement and deeper academic development, particularly because AI systems can rapidly provide explanations, summaries, recommendations, and solutions. Short-term improvements may result from more efficient access to instructional resources, but such gains do not necessarily demonstrate durable understanding, independent competence, or transferable knowledge. A systematic review of AI-supported personalized learning emphasizes that the educational impact of personalization depends on the design and implementation of AI technologies within higher education rather than on technological adoption alone (Merino-Campos, 2025). Academic achievement should consequently be interpreted in relation to the learning processes through which it is produced, including feedback utilization, self-regulation, sustained engagement, and the development of higher-order cognitive capacities. Table 6 synthesizes the principal relationships identified between AI-supported personalization and academic achievement while distinguishing technological mechanisms from the learner and pedagogical conditions that shape their effects.

Table 6. Synthesized Evidence on AI, Personalized Learning, and Academic Achievement

Evidence Source	Main Focus	Academic Outcome	Key Interpretation
Imran et al. (2025)	AI personalized learning	Academic performance and motivation	Personalization can support performance alongside motivational processes
Arifin (2026)	AI and academic performance	Academic achievement	Self-regulated learning, motivation, and digital literacy shape outcomes
Saleem et al. (2025)	Personalized learning systems	Performance and engagement	Academic and engagement outcomes can develop concurrently
Alifah & Hidayat (2025)	AI learning analytics	Personalized learning support	Learner data can inform targeted academic intervention
Hooda et al. (2022)	AI assessment and feedback	Student success	Responsive feedback can strengthen learning processes
Merino-Campos (2025)	AI personalization in higher education	Learning outcomes	Effectiveness depends on implementation and educational design

Table 6 shows that academic achievement is most consistently associated with AI personalization when adaptive technology is embedded within active learning, feedback, motivation, and self-regulatory processes. The evidence does not support an interpretation in which AI functions as an independent causal source of improved grades because the reported outcomes are shaped by pedagogical integration and students' capacity to use AI constructively. This finding is particularly relevant to higher education, where academic achievement is expected to reflect not only task completion but also the acquisition of durable knowledge and transferable intellectual skills. The synthesis indicates that personalization contributes greatest value when AI reduces unnecessary instructional mismatch while preserving students' responsibility for learning, evaluation, and academic decision-making. Academic achievement therefore represents an outcome that should be interpreted alongside critical thinking and learning engagement rather than examined as an isolated indicator of AI effectiveness. This integrated perspective provides the analytical basis for examining how the three outcomes interact within AI-supported personalized learning environments.

Integrated Relationship among Critical Thinking, Learning Engagement, and Academic Achievement

The synthesis across the reviewed literature indicates that critical thinking, learning engagement, and academic achievement should not be treated as independent consequences of AI-supported personalized learning because the three outcomes are connected through the quality of students' interaction with adaptive learning environments. Personalized AI systems can adjust content and learning pathways to individual needs, creating conditions that may increase students' willingness to participate while simultaneously providing opportunities for more cognitively demanding activities. Evidence from research on AI in personalized learning suggests that personalization can improve students' learning experiences by making instructional support more responsive to individual characteristics and learning progress (Iman et al., 2024). Engagement becomes particularly significant when students use personalized resources actively, because sustained participation increases opportunities for processing information, applying feedback, and developing academic understanding. Critical thinking represents a deeper cognitive dimension of this process because students must move beyond receiving personalized information toward evaluating evidence, questioning assumptions, and constructing independent judgments. Academic achievement can then be understood as a broader outcome that reflects the extent to which these cognitive and behavioural processes are converted into demonstrable learning performance. The integrated evidence therefore suggests that the educational value of AI-supported personalization is better explained through the interaction among these outcomes than through isolated measures of technological effectiveness.

The relationship among the three outcomes can be interpreted as a dynamic learning process in which personalization establishes the initial conditions for individualized participation, engagement sustains students' involvement, and critical thinking deepens the cognitive quality of that involvement. AI-supported formative assessment can reinforce this process by connecting students' learning activities with feedback that identifies areas requiring further attention and encourages subsequent engagement with academic tasks. Recent evidence on AI-integrated formative assessment specifically connects student engagement, learning styles, and learning outcomes, indicating that assessment processes can become an important link between personalized learning and academic development (Pratiwi et al., 2026). The integrated pattern identified from the literature is summarized in Table 7.

Table 7. Integrated Synthesis of AI-Supported Personalized Learning Outcomes

Ai-Supported Personalization Process	Learning Engagement	Critical Thinking	Academic Achievement
Adaptive Content	Increases relevance and participation	Encourages analysis of appropriately challenging material	Supports content mastery
Personalized Feedback	Sustains effort and persistence	Promotes reflection and evaluation	Facilitates correction of learning errors

Learning Analytics	Identifies engagement patterns	Supports awareness of cognitive weaknesses	Enables targeted intervention
Adaptive Assessment	Encourages active participation in evaluation	Develops evaluation and reasoning	Improves alignment between assessment and learning
Intelligent Assistance	Provides continuous interaction	Supports inquiry and independent reasoning	Facilitates clarification and problem solving
Personalized Learning Pathways	Supports learning continuity	Encourages independent learning decisions	Enables progression according to individual needs

Table 7 summarizes the finding that the same AI mechanism is linked to more than one educational outcome, supporting an integrated interpretation of personalized learning. Adaptive content is associated with stronger engagement through improved task relevance while also creating opportunities for critical thinking when the material requires analysis rather than simple recall. Personalized feedback can similarly affect engagement through persistence, critical thinking through reflection, and achievement through corrective learning. Research on AI-powered educational tools indicates that engagement and learning outcomes are interconnected with the effectiveness of teaching practices through which AI is implemented (Naseer et al., 2026). This relationship suggests that AI personalization should be understood as a pedagogical infrastructure that shapes learning opportunities rather than as a self-sufficient educational intervention. The quality of outcomes depends on whether students are encouraged to transform personalized assistance into active intellectual work. The integrated findings therefore support an interpretation in which personalization provides the adaptive conditions, engagement provides sustained participation, and critical thinking provides cognitive depth, while academic achievement represents an important manifestation of the resulting learning process.

The literature also indicates that the relationship among the three outcomes is strongly influenced by teaching methods and the broader pedagogical environment in which AI is deployed. Adaptive technologies can provide individualized resources, but instructors remain important in designing tasks that require students to interpret information, engage in discussion, evaluate AI-generated outputs, and apply knowledge to unfamiliar problems. A systematic review of AI in higher education identifies teaching methods as an important factor in explaining variations in student engagement, suggesting that technological personalization alone cannot guarantee meaningful participation (Long et al., 2026). This finding is especially relevant to critical thinking because students require pedagogically structured opportunities to challenge information and justify conclusions rather than merely receive personalized answers. Academic achievement is also likely to benefit when engagement and cognitive processing are reinforced through coherent instructional sequences, assessment practices, and feedback. AI personalization consequently appears most effective when it operates within a human-guided learning environment in which technology and pedagogy perform complementary functions. The integrated model emerging from the literature is therefore neither technology-centred nor teacher-centred, but oriented toward a coordinated relationship among AI adaptation, instructional design, learner agency, and academic development.

A further pattern concerns the importance of student agency in determining whether personalization produces meaningful educational outcomes. AI systems can individualize learning pathways, but students remain responsible for deciding how to interpret recommendations, evaluate information, manage their learning, and use technological assistance in academically appropriate ways. Research on AI and academic performance demonstrates that self-regulated learning, motivation, and digital literacy can shape the relationship between AI use and academic achievement, reinforcing the importance of learner characteristics in determining educational outcomes (Arifin, 2026). This perspective also helps explain why increased engagement should not automatically be interpreted as evidence of stronger critical thinking because students may participate actively while relying excessively on AI-generated explanations or solutions. A productive learning environment requires students to maintain cognitive responsibility while using AI to extend rather than replace their intellectual activities. Personalization is therefore educationally valuable when it supports learner autonomy and enables students to make progressively more informed decisions about their learning. The synthesis indicates that the strongest theoretical interpretation of AI-supported personalized

learning is consequently based on augmented learner agency, in which technological adaptation expands learning opportunities while students retain responsibility for cognition and academic judgment.

The final synthesis reveals that AI-supported personalized learning has the greatest educational significance when critical thinking, learning engagement, and academic achievement are treated as mutually reinforcing dimensions of learning rather than isolated outcomes. Recent research on AI and personalized learning identifies personalization, engagement, motivation, and learning outcomes as interconnected dimensions whose effects depend on implementation and pedagogical context (Adewale, 2026). The literature also suggests that AI can contribute to educational equity by adapting learning experiences to differences among students, although such potential depends on access, digital competence, instructional support, and responsible implementation (Feng et al., 2025). This broader perspective places AI personalization within the social and educational mission of higher education, where technological innovation should be evaluated according to whether it strengthens meaningful participation, independent thought, and demonstrable academic development. The integrated findings indicate that AI should not be conceptualized simply as an automated provider of individualized content, but as a mediating technology whose educational effects emerge through interactions among personalization, pedagogy, learner agency, and assessment. The evidence therefore supports a conceptual position in which engagement provides the behavioural and motivational foundation for learning, critical thinking provides cognitive depth, and academic achievement reflects the extent to which these processes produce meaningful educational outcomes. This integrated interpretation also clarifies the central research gap: understanding AI-supported personalized learning requires attention to how these three dimensions operate together rather than measuring technological effectiveness through a single educational outcome.

CONCLUSION

The integrative literature synthesis identifies differentiated relationships between AI-supported personalized learning and the three educational outcomes examined. Regarding critical thinking, adaptive questioning, reflective feedback, individualized instructional challenges, and intelligent assistance emerge as potential mechanisms for supporting reasoning and independent evaluation, although the evidence does not consistently establish measurable improvements attributable specifically to personalization. Regarding learning engagement, the reviewed literature provides more consistent descriptions of associations between instructional responsiveness, individualized support, motivation, and sustained participation, but behavioural interaction with AI systems cannot independently demonstrate cognitive engagement. Regarding academic achievement, personalized assessment, adaptive feedback, and self-regulated learning are associated with reported educational benefits, although variation in research designs and outcome measures restricts conclusions concerning their magnitude and generalizability. The synthesis identifies common instructional conditions across these domains, particularly meaningful learning tasks, appropriate cognitive demands, effective feedback, and opportunities for learner autonomy. However, the available evidence does not demonstrate that increased engagement necessarily improves critical thinking or that these outcomes produce subsequent gains in academic achievement. The principal contribution of this review is an integrated distinction between educational outcomes supported by reported associations and explanatory relationships that remain theoretically plausible but insufficiently verified.

The findings indicate that the educational value of AI-supported personalization cannot be established through technological functionality alone and must be assessed in relation to instructional design, learner characteristics, and the quality of student engagement. The review contributes a multidimensional interpretative framework connecting technological adaptation with cognitive, behavioural, and academic outcomes without treating these dimensions as components of an empirically verified causal sequence. Its conclusions remain limited by the bounded literature corpus, the absence of a reproducible database-specific search and selection record, the lack of standardized methodological quality appraisal, and differences in the technologies, educational settings, and outcome measures represented in the reviewed publications. These limitations restrict claims concerning the comprehensiveness of the evidence and the generalizability of the identified relationships. Future investigations should employ longitudinal and comparative designs, clearly specified personalization interventions, validated critical-thinking and engagement measures, and objective indicators of

academic achievement. Particular attention should be directed toward testing whether engagement and self-regulated learning explain relationships between adaptive instructional support and academic performance while accounting for digital competence, previous academic attainment, and institutional context. The available scholarship supports AI personalization as a potentially valuable form of instructional assistance, but its contribution to sustained cognitive development and academic achievement requires more direct and methodologically comparable empirical evidence.

REFERENCES

- Adewale, O. A. (2026). The impact of artificial intelligence on personalized learning, student engagement, and motivation in higher education: A systematic review. *International Journal of Applied Resilience and Sustainability*, 2(2), 1156-1187. <https://doi.org/10.70593/deepsci.0202048>.
- Alifah, N., & Hidayat, A. R. (2025). Effectiveness of artificial intelligence-based learning analytics tool in supporting personalized learning in higher education. *Jurnal Pendidikan Progresif*, 15(1), 74-84. <https://jpp.fkip.unila.ac.id/index.php/jpp/article/view/41>.
- Anuyahong, B., Rattanapong, C., & Patcha, I. (2023). Analyzing the impact of artificial intelligence in personalized learning and adaptive assessment in higher education. *International Journal of Research and Scientific Innovation*, 10(4), 88-93. <https://doi.org/10.51244/IJRSI.2023.10412>.
- Arifin, I. (2026). Artificial Intelligence and Academic Performance in Higher Education: The Mediating Role of Self-Regulated Learning and the Influence of Learning Motivation and Digital Literacy. *Management of Education: Jurnal Manajemen Pendidikan Islam*, 12(1), 76-88. <https://doi.org/10.18592/moe.v12i1.20395>.
- Bolarinwa, T. (2026). The impact of artificial intelligence on students' academic development, critical thinking, cognitive skills, and learning outcomes. *International Journal of Applied Resilience and Sustainability*, 2(2), 1097-1129. <https://doi.org/10.70593/deepsci.0202045>.
- Faizi, W. U. N., Akhtar, S., & Butt, M. A. (2026). The Impact of Artificial Intelligence-Assisted Learning on Academic Performance and Critical Thinking Skills Among Undergraduate Students. *Social Science Review Archives*, 4(2), 2925-2948. <https://policyjournalofms.com/index.php/6/article/view/2401>.
- Feng, Z., Sudatha, I. G. W., & Sudarma, I. K. (2025). Artificial Intelligence and the Future of Learning: Personalization for Equity and Engagement. *Journal of Education Technology*, 9(4). <https://doi.org/10.23887/jet.v9i4.103236>.
- Hariyanto, Kristianingsih, F. X. D., & Maharani, R. (2025). Artificial intelligence in adaptive education: a systematic review of techniques for personalized learning. *Discover Education*, 4(1), 458. <https://doi.org/10.1007/s44217-025-00908-6>.
- Hassan, A. (2026). Leveraging artificial intelligence (AI) to enhance student engagement and academic performance in higher education. *Education and Information Technologies*, 1-27. <https://doi.org/10.1007/s10639-026-13946-w>.
- Hidayat, A., Maryana, M., Rustiyana, R., & Winarko, T. (2025). Artificial intelligence in personalized learning: Enhancing student engagement through adaptive learning systems. *Journal Emerging Technologies in Education*, 3(4), 175-184. <https://doi.org/10.70177/jete.v3i4.2508>.
- Hooda, M., Rana, C., Dahiya, O., Rizwan, A., & Hossain, M. S. (2022). Artificial intelligence for assessment and feedback to enhance student success in higher education. *Mathematical Problems in Engineering*, 2022(1), 5215722. <https://doi.org/10.1155/2022/5215722>.
- Iman, M. Z., Asis, A. A., & Rahma, A. U. Z. (2024). Enhancing personalized learning: the impact of artificial intelligence in education. *Edu Spectrum: Journal of Multidimensional Education*, 1(2), 101-112. <https://doi.org/10.70063/eduspectrum.v1i2.55>.
- Imran, H., Nadeem, S., Khan, M. L., & Qureshi, U. (2025). Impact of artificial intelligence personalized learning on student motivation and academic performance. *SOCIUM Учёным: Jomard Publishing*, 2(1), 49-58. <https://doi.org/10.62476/soc.2149>.
- Long, D. Y., Wang, S., Md Rashid, S., & Lu, X. T. (2026, February). Artificial intelligence in higher education: A systematic review of its impact on student engagement and the mediating role of teaching methods. In *Frontiers in Education* (Vol. 10, p. 1648661). Frontiers. <https://doi.org/10.3389/feduc.2025.1648661>.

- Manaf, S., & Mufid, A. (2026). Integration of Artificial Intelligence (AI) in Adaptive Learning: A Personalized Analysis of Student Learning Experience in the Digital Era. *At-Tathbīq: Journal of Education and Learning*, 2(1), 1-9. <https://doi.org/10.65097/jel.v2i1.125>
- Merino-Campos, C. (2025). The impact of artificial intelligence on personalized learning in higher education: A systematic review. *Trends in Higher Education*, 4(2), 17 <https://doi.org/10.3390/higheredu4020017>
- Miranda, E. (2025, December). A Systematic Review Of Artificial Intelligence Integration In Digital Learning For Higher Education: Technologies, Personalization, And Implementation Challenges. In *2025 11th International HCI and UX Conference in Indonesia (CHIuXiD)* (pp. 1-6). IEEE. <https://doi.org/10.1109/CHIuXiD68326.2025.11323807>
- Naseer, F., Shahid, S., & Bashir, M. (2026). Artificial Intelligence in Higher Education: Exploring the Impact of AI-Powered Tools on Teaching Effectiveness, Student Engagement, and Learning Outcomes through a Systematic Qualitative Review. *ASSAJ*, 5(2), 689-716. <https://www.assajournal.com/index.php/36/article/view/1730>.
- Palappetty, M. S. (2026). Human Artificial Intelligence Collaboration in Higher Education: A Conceptual Framework for Enhancing Critical Thinking and Academic Performance. *International Journal of Advanced and Innovative Research (IJAIR)*, 2(2), 33-50. <https://scholarclub.org/index.php/IJAIR/article/view/214>.
- Peng, J., & Li, Y. (2025). Frontiers of artificial intelligence for personalized learning in higher education: A systematic review of leading articles. *Applied Sciences*, 15(18), 10096. <https://doi.org/10.3390/app151810096>.
- Pratiwi, H., Sa'ad, M. I., Hikmah, N., & Prima, A. (2026). Integrating Artificial Intelligence in Formative Assessment: Connecting Student Engagement, Learning Styles, and Learning Outcomes. *Journal of Pedagogy and Education Science*, 5(01), 190-206. <https://doi.org/10.56741/IISTR.jpes.001513>.
- Sajja, R., Sermet, Y., Cikmaz, M., Cwierty, D., & Demir, I. (2024). Artificial intelligence-enabled intelligent assistant for personalized and adaptive learning in higher education. *Information*, 15(10), 596. <https://doi.org/10.3390/info15100596>.
- Saleem, S., Aziz, M. U., Iqbal, M. J., & Abbas, S. (2025). AI in education: Personalized learning systems and their impact on student performance and engagement. *The critical review of social sciences studies*, 3(1), 2445-2459. <https://doi.org/10.59075/c35qa453>.
- Sriwahyuni, N. (2026). Artificial Intelligence-Supported Personalized Learning for Enhancing Students' Critical Thinking Skills: A Systematic Literature Review. *Journal of Learning Innovation and Educational Technology*, 1(1), 39-59. <https://jurnal.suriaacademicpress.com/index.php/JLIET/article/view/109>.