

DIGITAL TRANSFORMATION AND ARTIFICIAL INTELLIGENCE IN IMPROVING LEARNING EFFECTIVENESS

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Abstract

This research aims to analyze the role of digital transformation and artificial intelligence in enhancing learning effectiveness through a literature review. Research data were obtained from scientific articles, books, proceedings, and reports from official institutions relevant to *digital transformation*, *artificial intelligence in education*, *adaptive learning*, *student engagement*, and *learning effectiveness*. Literature was selected based on relevance, quality of sources, availability of complete texts, and publication priorities of the last five years. The analysis is carried out in the following stages: identification, screening, feasibility assessment, theme grouping, and narrative synthesis. The results of the study show that digital transformation and artificial intelligence can increase learning effectiveness through material personalization, intelligent tutoring systems, automated feedback, learning analytics, prediction of learning difficulties, and increased flexibility and student engagement. However, the effectiveness of its implementation is greatly influenced by teacher readiness, digital competence, pedagogical design quality, technological infrastructure, organizational culture, and institutional policy support. The study also found a number of challenges, including access gaps, algorithmic bias, personal data protection, academic integrity, technology dependence, and the potential for a decrease in critical thinking skills if AI is used unsupervised. Therefore, AI should be positioned as a supporting tool that strengthens the role of teachers, not as a substitute for educators' pedagogical, social, and emotional functions. This research confirms the importance of human-centered, inclusive, ethical, transparent, and sustainable AI integration models. The study's implications underscore the need to improve educators' digital competence, AI governance policies, equitable infrastructure distribution, and continuous evaluation so that digital transformation truly improves the quality and effectiveness of learning. In addition, further research needs to empirically test the longitudinal impact of AI across various levels of education, fields of study, learner characteristics, and social contexts.

Keywords: digital transformation; artificial intelligence; learning effectiveness; educational technology; adaptive learning.

Introduction

Digital transformation has become one of the most significant changes in the modern education system. The development of online learning platforms, mobile devices, cloud computing, learning analytics, and artificial intelligence (AI) has changed the way materials are delivered, learning interactions are carried out, and student achievements

are evaluated. AI enables educational institutions to provide more adaptive, personalized, flexible, and data-driven learning. This technology can also help teachers organize materials, provide feedback, identify learning difficulties, and reduce administrative burden. UNESCO affirms that AI has the potential to address various educational challenges and accelerate the achievement of quality education, but its implementation must remain human-oriented, inclusive, and equitable (UNESCO, 2025).

While digital transformation and AI offer a variety of benefits, their implementation has not always resulted in consistent improvements in learning effectiveness. Various educational institutions have used learning management systems, smart tutors, chatbots, automated assessment applications, and material recommendation systems, but some of their use is still technical and has not been integrated with pedagogical strategies. AI can support learning personalization, provide real-time feedback, and help educators tailor learning to learners' needs. However, evidence on the effectiveness and scalability of AI interventions in real learning environments is still limited, requiring more systematic testing (Molina et al., 2024).

The phenomenon gap can be seen from the difference between the rapid adoption of digital technology and the resulting improvement in the quality of learning. The availability of technology does not guarantee that students become more active, independent, critical, and able to achieve better learning outcomes. On the one hand, AI can increase engagement, provide academic support, and tailor content to individual abilities. On the other hand, the excessive use of AI can cause technology dependence, reduce the ability to think deeply, widen the digital divide, and raise privacy and academic integrity issues. Recent studies show that the benefits of AI in education coexist with challenges in the form of unethical use, educator resistance, digital dependence, and unequal access to technology (Garzón et al., 2025).

Based on these conditions, the research problem lies in the lack of clarity of mechanisms that explain how digital transformation and the use of AI can improve learning effectiveness. The effectiveness of learning is not only determined by the availability of devices and applications, but also by teacher readiness, students' digital competence, learning design, information quality, human and technological interaction, and institutional support. If AI is used without a proper pedagogical approach, it has the potential to only accelerate task completion without improving conceptual understanding and critical thinking skills. Therefore, research needs to analyze the influence of digital transformation and AI on student engagement, motivation, learning personalization, learning process efficiency, and academic achievement (Vieriu & Petrea, 2025).

The research gap arises because most previous studies tend to address AI applications, technology acceptance, or learning outcomes separately. Research on AI in education is also spread across various disciplines, using various theories, methods, levels of education, and effectiveness indicators. Wang et al. (2024) show that AI research in education includes adaptive learning, personalized tutoring, intelligent assessment, performance prediction, and education management, but there are still implementation

topics and contexts that have not been adequately explored. In addition, research on the development of teachers' competencies in integrating AI is still more limited than the discussion of the use of AI by students (Tan et al., 2025).

The novelty or incremental development of this research lies in the integration of digital transformation and the use of AI in an analytical framework to explain the improvement of learning effectiveness more comprehensively. Digital transformation is positioned not just as the provision of infrastructure, but as systemic change that includes learning strategies, educator competence, digital culture, data management, and institutional governance. Meanwhile, AI is understood as a decision-support and personalization instrument that still requires human supervision. The approach allowed the research to identify the relationship between digital readiness, the quality of AI use, learner engagement, the role of teachers, and learning outcomes. Human-centric orientation is also important because end-user engagement, human control, security, reliability, and trust are still underpaid in educational AI system design (Alfredo et al., 2023).

The urgency of this research is getting stronger because educational institutions cannot avoid the development of AI, but also cannot adopt it without pedagogical, ethical, and institutional evaluation. Empirical evidence is needed to ensure that technology investments actually improve the quality of learning processes and outcomes, rather than simply expanding the use of digital devices. The results of the research are expected to provide a basis for schools, colleges, educators, and policymakers in designing AI-based learning that is effective, inclusive, safe, and responsible. Thus, research on *Digital Transformation and Artificial Intelligence in Improving Learning Effectiveness* is important to produce a technology implementation model that is able to strengthen the role of teachers, maintain student independence, reduce the digital divide, and increase learning effectiveness in a sustainable manner.

Research Methods

This study uses a library *research method* with a systematic literature review approach to analyze the role of digital transformation and artificial intelligence in increasing learning effectiveness. The research data is in the form of scientific articles, books, conference proceedings, and official institution reports that discuss digital technology, artificial intelligence, adaptive learning, student involvement, educator digital competence, and learning outcomes. Literature sources were searched through academic databases such as Scopus, Web of Science, ScienceDirect, SpringerLink, and Google Scholar using a combination of the keywords *digital transformation, artificial intelligence in education, learning effectiveness, adaptive learning, student engagement, and educational technology*. Literature was selected based on relevance to the research topic, quality of sources, availability of complete texts, and preferred publications from the last five years. The analysis process is carried out through several stages, namely literature identification, filtering based on titles and abstracts, content feasibility assessment, thematic grouping,

and synthesis of findings. Articles that are not directly related to the use of digital technology and AI in the learning process, do not have methodological clarity, or contain repetitive information are excluded from the analysis. The selected literature was analyzed using content analysis techniques by identifying the benefits, challenges, supporting factors, risks, and impacts of digital transformation and AI on learning effectiveness. The results of the analysis are then compared and synthesized narratively to gain a comprehensive understanding of the patterns of research findings, knowledge gaps, and recommendations for the application of AI that is effective, inclusive, ethical, and oriented to the needs of students.

Results and Discussion

Results

The results of the literature study show that digital transformation in education is no longer limited to the use of computer devices, the internet, and *learning management systems*, but has developed into a comprehensive change in the learning process, institutional governance, curriculum, educator competence, and student experience. Digital technology allows learning to be conducted more flexibly, openly, collaboratively, and not limited by space or time. In the context of Education 4.0, the learning process is starting to shift from a teacher-centered approach to student-centered, experiential, and tailored to individual needs. However, the success of such transformation requires integration between digital leadership, human resources, technological infrastructure, organizational culture, and a clear pedagogical strategy (McCarthy et al., 2023; Mukul & Büyüközkan, 2023).

The results of the literature synthesis also show that artificial intelligence contributes positively to learning effectiveness, especially through adaptive learning, intelligent tutoring systems, material recommendations, prediction of learning difficulties, and automatic feedback. Meta-analysis Zheng et al. (2023) found that the use of AI exerts a strong influence on learning achievement, although its influence on learners' perceptions is smaller. More recent findings also show that the application of AI in education produces a positive influence on learning achievement, but the magnitude of the influence is influenced by the field of study, level of education, mode of learning, duration of intervention, and the form of AI application used (Tlili et al., 2025; Zheng et al., 2023). As such, AI does not automatically result in effective learning as its benefits remain determined by its design and the context in which it is used.

Personalization is one of the most prominent outcomes of integrating AI in learning. AI-based systems can analyze students' initial abilities, learning speed, error patterns, mastery levels, and preferences to determine appropriate materials and activities. A meta-analysis of 99 effect measures from 32 experimental studies found that AI-based personal STEM learning produced a significant positive effect compared to learning without AI, with an overall effect size of $g = 0.455$. The influence is stronger when AI is integrated with teacher engagement, collaborative learning, project-based learning,

and immersive technologies such as *augmented reality* and *virtual reality*. This suggests that personalization technology will be more effective when used as part of a structured learning design, rather than as a self-paced learning tool that completely replaces educators (Li et al., 2025).

In addition to improving academic achievement, the use of digital technology and AI has been found to strengthen students' motivation, engagement, problem-solving, AI literacy, and understanding. In science education, AI is used to create interactive learning environments, compile quizzes, assess learners' work, predict performance, and provide faster feedback. In primary and secondary education, AI learning that uses practical activities, projects, discussions, and problem-solving can increase AI literacy, positive attitudes towards technology, ethical reflection, and students' interest in the field of technology. However, the increase in engagement tends to be stronger when students not only receive answers from AI, but are also asked to test, explain, compare, and revise the information generated by the system (Almasri, 2024; Lee & Kwon, 2024).

The results of the study also found a number of obstacles that can reduce the effectiveness of the implementation of digital transformation and AI. These barriers include limited infrastructure, access gaps, low digital competence, resistance to change, information inaccuracy, algorithmic bias, personal data protection, academic integrity, and students' dependence on technology. In addition, AI's ability to understand the context of the subject, the character of students, and the social conditions of learning is still not uniform. Research on AI in higher education is also still dominated by discussions of technology and applications, while the issues of international collaboration, educator involvement, ethics, and methodological quality have not received balanced attention. Therefore, the benefits of AI need to be accompanied by human supervision, critical literacy, usage policies, and sustainable evaluation mechanisms (Akgun & Greenhow, 2022; Bond et al., 2024; Crompton et al., 2024).

Discussion

The findings of the study show that digital transformation must be understood as the transformation of the education system, not just the digitization of materials or the transfer of learning to online platforms. The availability of technology is only an initial prerequisite, while the effectiveness of learning is determined by the institution's ability to connect technology with the curriculum, teaching methods, assessment, leadership, and needs of students. Institutions that only invest in devices without making pedagogical changes risk resulting in administrative digitalization that does not have a significant impact on the quality of learning. Thus, effective digital transformation requires visionary leadership, competency development, a culture of innovation, technical support, and learning outcome-based evaluation (McCarthy et al., 2023; Mukul & Büyüközkan, 2023).

The positive influence of AI on learning effectiveness can be explained through three main mechanisms, namely personalization, direct feedback, and data-driven decision-making. Personalization helps reduce mismatches between the material and the

learner's abilities, while immediate feedback allows mistakes to be corrected before they become a persistent misconception. At the same time, learning analytics helps teachers identify students who are at risk of difficulties, determine interventions, and adjust teaching strategies. However, variations in outcomes between learning showed that the effectiveness of AI was influenced by the type of technology, user characteristics, subjects, education level, and interaction patterns between teachers, students, and AI systems. Therefore, the claim that AI is always more effective than conventional learning needs to be treated critically (Li et al., 2025; Tlili et al., 2025; Zheng et al., 2023).

The role of teachers remains a central factor because AI is more appropriately placed as a tool to strengthen the capacity of educators, rather than replacing their pedagogical and social functions. Teachers are needed to verify AI outputs, explain context, provide emotional support, build social interactions, and design activities that encourage critical and creative thinking. However, research on AI in education still discusses the use of technology for students more than its use in teacher professional development. This condition demonstrates the need for training that not only teaches how to operate an application, but also includes learning design, instruction engineering, information evaluation, AI ethics, data privacy, and strategies to prevent cognitive dependency (Bond et al., 2024; Tan et al., 2025).

Based on the overall findings, improving learning effectiveness requires a human-centered, inclusive, transparent, and accountable AI integration model. Educational institutions need to set application selection standards, data protection, bias checking, material validation, as well as limits on the use of AI in assignments and assessments. Learning assessment also needs to be directed at argumentation, reflection, authentic problem-solving, presentation, and the process of creating works so that students do not just hand over AI outputs. Further research needs to use experimental and longitudinal designs to compare short-term and long-term learning outcomes, measure critical thinking skills, and test the application of AI at various levels, disciplines, and social groups. This approach is needed so that digital transformation and AI truly improve the equity and quality of education, not increase the gap and dependence on technology (Akgun & Greenhow, 2022; Almasri, 2024; Crompton & Burke, 2024).

Conclusion

Based on the results of the study, digital transformation and the application of artificial intelligence have great potential to increase the effectiveness of learning through material personalization, direct feedback, adaptive learning, increased student involvement, and data-driven decision-making. However, the success of its implementation is not only determined by technological sophistication, but also by the readiness of teachers, students' digital competence, the quality of pedagogical design, institutional support, and ethical and responsible governance. AI should be placed as a supporting tool that strengthens the role of educators, not replacing the pedagogical, social, and emotional functions of teachers. Therefore, educational institutions need to

develop policies on the use of AI, digital competency training, data protection, equal access, and continuous evaluation systems so that digital transformation is truly able to improve the quality, inclusivity, and sustainability of learning.

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