Artificial Intelligence in Education: Theoretical Frameworks, Applications, and Emerging Challenges

Maria Flori[1], Daniel Hunyadi[2] and Ralf Fabian[3]

[1,2,3] Lucian Blaga University of Sibiu, Sibiu 550024, Romania
maria.flori@ulbsibiu.ro

Abstract. The digital transformation of education, accelerated by the COVID-19 pandemic, has led to the extensive integration of artificial intelligence (AI) into teaching and learning processes. This paper examines the role of AI in reshaping education through a systematic literature review complemented by a narrative synthesis. The aim of the study is to identify the main theoretical frameworks, applications, benefits, and challenges associated with the use of AI in education within the context of the Education 4.0 paradigm.

The analysis is grounded in relevant theoretical models, including self-regulated learning (Zimmerman), the TPACK framework, and constructive alignment (Biggs), highlighting how AI-based technologies support personalized learning, adaptive feedback, and the development of metacognitive skills. Applications such as adaptive systems, intelligent tutoring systems, learning analytics, and generative artificial intelligence are examined, emphasizing their impact on the educational experience.

The findings indicate that AI significantly contributes to improving the efficiency of educational processes, enhancing accessibility, and supporting self-regulated learning. However, major challenges are also identified, including ethical risks, algorithmic bias, privacy concerns, and inequalities in access. The paper highlights the need for governance frameworks and educational policies that ensure the responsible and equitable implementation of AI.

The conclusions emphasize the importance of maintaining a balance between technological innovation and the essential role of the teacher in the educational process.

Keywords: Artificial Intelligence, Educational Management, Adaptive Learning, Education 4.0, Generative AI, Digital Transformation, Educational Inclusion.

1 Introduction

1.1 Context of digital transformation in education

The digital transformation of education is no longer a mere trend but a structural reality that is reshaping how knowledge is created, distributed, and internalized. Two decades ago, Learning Management Systems (LMS) such as Moodle or Blackboard represented

D. Mara and I. D. Hunyadi (eds.), *Proceedings of the International Conference on Management and Entrepreneurial Leadership for K-12 Education Excellence (LEADK12 2026)*, Advances in Social Science, Education and Humanities Research 1026,
https://doi.org/10.2991/978-2-38476-599-7_5

the forefront of innovation; however, they primarily functioned as static repositories of content. Students accessed materials, completed assessments, and engaged in limited interaction with digital environments that did not dynamically respond to their individual needs. This approach has been widely criticized for its lack of personalization and for replicating traditional teaching models in a digital format (Selwyn 2016).

With the advancement of artificial intelligence (AI), education has entered a new phase characterized by adaptivity, automation, and advanced data analytics. Contemporary systems not only deliver content but also adjust it in real time based on user performance and behavior. This shift reflects the transition from digitalization—defined as the use of technology to support existing processes—to genuine digital transformation, where technology fundamentally redefines educational practices (Bond et al. 2018).

The COVID-19 pandemic significantly accelerated this transition. According to UNESCO (2021), over 1.6 billion learners were affected by school closures, prompting institutions worldwide to rapidly adopt digital solutions. In this context, AI has emerged as a critical tool for scaling education and ensuring continuity of learning.

Definition of Education 4.0

The concept of Education 4.0 is closely linked to the paradigm of Industry 4.0 and reflects the need for educational systems to adapt to a highly digitalized and interconnected society. Education 4.0 involves the integration of intelligent technologies, such as artificial intelligence, the Internet of Things (IoT), and augmented reality, into teaching and learning processes (Hussin 2018).

From an operational perspective, Education 4.0 can be defined through several key dimensions. First, personalized learning enables the adaptation of content and pace according to individual learner needs. Second, the focus shifts from memorization to the development of 21st-century skills, including critical thinking, collaboration, and complex problem-solving. Third, intelligent technologies facilitate real-time feedback and continuous performance analysis.

An additional core dimension is the integration of ethics and equity in the use of technology. AI systems are not neutral; they reflect the data and algorithms on which they are built. Therefore, Education 4.0 entails not only technological innovation but also social responsibility.

Relevance of the study

The adoption of artificial intelligence in education has grown exponentially in recent years. According to a HolonIQ (2023) report, global investments in EdTech have exceeded $20 billion annually, with a substantial share directed toward AI-based solutions. Furthermore, a McKinsey (2022) study indicates that over 60% of higher education institutions have begun experimenting with or implementing AI technologies.

The emergence of large language models (LLMs), such as GPT-4 and Claude, has fundamentally transformed the way educational content is generated and utilized. These technologies are capable of producing coherent text, explaining complex concepts, and providing personalized feedback, raising important questions about the role of educators and the authenticity of learning processes (Kasneci et al. 2023).

The relevance of this topic is further amplified by associated challenges, including inequalities in access, ethical risks, and the need for appropriate regulatory frameworks.

Consequently, analyzing the integration of AI in education is both timely and necessary for the development of sustainable strategies.

Research aims and objectives

The primary aim of this study is to examine how artificial intelligence is transforming the educational process from the perspectives of theoretical frameworks, practical applications, and social and ethical implications. The paper seeks to provide a comprehensive synthesis of the existing literature, identifying both the benefits and limitations of these technologies.

The specific objectives include identifying key trends in the use of AI in education, analyzing relevant theoretical models, and evaluating their impact on teaching and learning processes. Additionally, the study aims to highlight emerging challenges, such as algorithmic bias and technological dependency, and to formulate recommendations for educational policy.

Another important objective is to explore how AI can support self-regulated learning and the development of metacognitive skills, thereby contributing to the broader academic discourse on the future of education.

Research questions

To guide the analysis, the following research questions were formulated:

- How can artificial intelligence support self-regulated learning?
- What are the main benefits and limitations of integrating AI in education?
- What ethical and equity-related challenges arise from the use of these technologies?
- How can educational institutions implement AI in a responsible and sustainable manner?

These questions reflect the complexity of the topic and the need for an interdisciplinary approach.

Figure 1 illustrates the conceptual ecosystem of artificial intelligence integration within Education 4.0 environments. The model emphasizes the dynamic interactions between AI-driven technologies, pedagogical models, learning processes, governance structures and institutional transformation processes that collectively shape educational outcomes in digitally enhanced educational ecosystems.

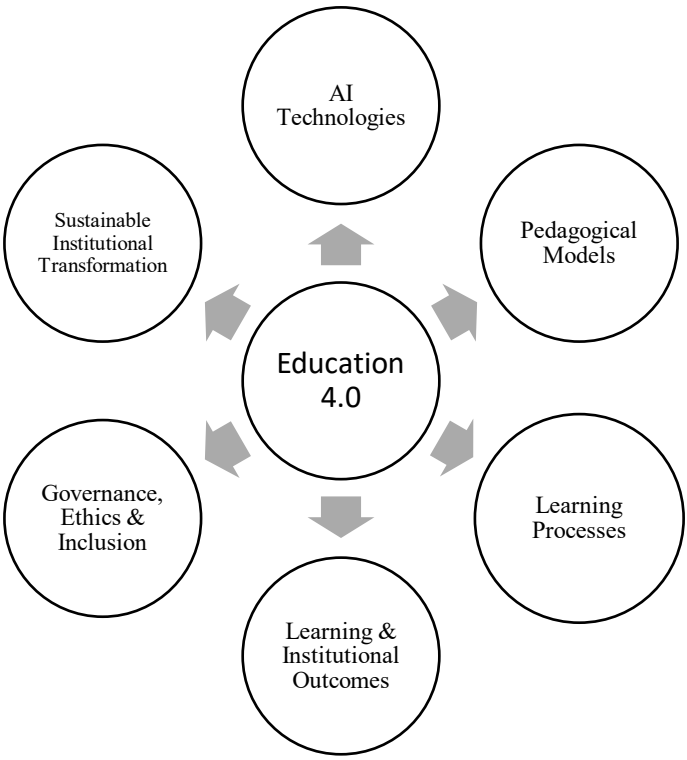

Fig. 1. Education 4.0 Ecosystem for AI-Enhanced Learning and Institutional Transformation

The ecosystem perspective presented in Figure 1 supports the systemic orientation of the chapter by illustrating that AI integration extends beyond technological implementation and involves continuous interactions between pedagogical, organizational and governance dimensions.

2 Theoretical Framework

2.1 Evolution of educational technologies and artificial intelligence

The evolution of educational technologies can be understood as a process of progressive layering, where each stage introduces increasing levels of complexity and interactivity. Early digital systems used in education were characterized by linear structures and limited interaction. Traditional Learning Management Systems (LMS) provided access to resources and supported course administration, but they lacked the capacity to adapt learning experiences to individual needs.

The emergence of adaptive systems marked a significant turning point. These systems employ algorithms to analyze user performance and adjust content accordingly. For instance, Intelligent Tutoring Systems (ITS) can identify knowledge gaps and pro-

vide personalized exercises (Woolf, 2010). In recent years, the development of generative AI has opened new perspectives. Large language models are capable of generating educational content, simulating dialogue, and providing explanations tailored to the learner's level. Recent studies suggest that these technologies can significantly enhance the learning experience, while also raising concerns related to accuracy and ethics (Kasneci et al. 2023).

This evolution reflects a broader shift from technology as a supporting tool to technology as an active partner in the educational process.

2.2 Relevant theoretical models

The integration of artificial intelligence in education cannot be fully understood without robust theoretical frameworks that explain how learning occurs and how it can be optimized. Technology, regardless of its sophistication, must be grounded in validated pedagogical principles. In this context, three theoretical models are particularly relevant: self-regulated learning, the TPACK framework, and constructive alignment.

These models provide a conceptual foundation for the effective integration of AI in education. For example, adaptive systems and intelligent tutors can be designed to support the metacognitive processes described by Zimmerman. At the same time, educators are required to integrate technological, pedagogical, and content knowledge, as emphasized by the TPACK model (Mishra & Koehler 2006). Furthermore, the use of AI should be aligned with learning objectives and assessment methods, in accordance with the principles of constructive alignment (Biggs 1996).

There is a growing consensus in the literature that the integration of AI without a solid theoretical foundation may lead to suboptimal outcomes or even negative effects on learning (Luckin et al. 2016). Therefore, these models serve not only as analytical frameworks but also as practical guides for implementation.

Figure 2 illustrates the conceptual integration of the principal theoretical models supporting AI-enhanced learning environments. The framework demonstrates how constructive alignment, self-regulated learning and technological-pedagogical integration collectively contribute to adaptive and digitally enhanced educational processes.

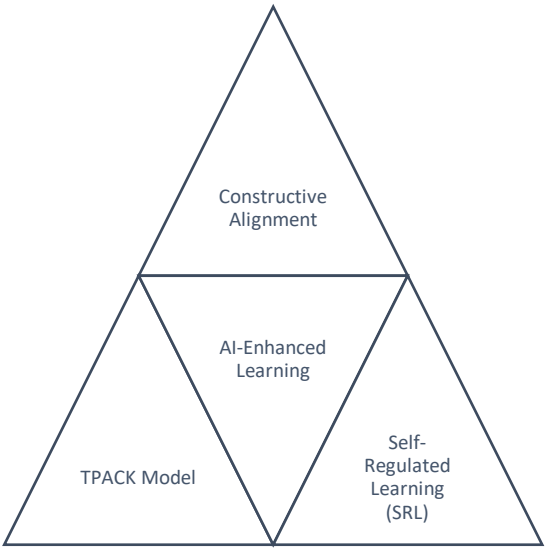

Fig. 2. Conceptual Integration of Theoretical Models Supporting AI-Enhanced Learning

The interaction between these theoretical perspectives highlights that effective AI integration in education depends on the alignment between pedagogical design, learner autonomy and technological competence.

2.2.1. Self-Regulated Learning Model (Zimmerman)

The self-regulated learning model developed by Barry Zimmerman (2002) is one of the most influential frameworks in educational psychology. It conceptualizes learning as an active and cyclical process in which learners plan, monitor, and evaluate their own progress. The model is structured around three main phases: forethought, performance, and self-reflection.

Artificial intelligence can play a significant role in each of these phases. During the forethought phase, AI systems can assist learners in setting realistic goals and organizing their learning activities. For example, educational platforms may recommend personalized learning paths based on user data. In the performance phase, AI can provide real-time feedback by identifying errors and suggesting corrections, thereby supporting motivation and improving performance.

In the self-reflection phase, learning analytics tools enable learners to assess their progress and identify effective strategies. Research indicates that the use of interactive dashboards can enhance metacognitive awareness (Jivet et al., 2018). However, excessive reliance on automated feedback may reduce the development of authentic self-reflection skills.

Thus, while AI can effectively support self-regulated learning, its use should be carefully balanced to avoid replacing essential cognitive processes.

2.2.2 TPACK Model

The TPACK (Technological Pedagogical Content Knowledge) model, proposed by Mishra and Koehler (2006), provides an integrative framework for understanding the competencies required of educators in digital environments. It emphasizes that effective technology integration depends on a balanced combination of technological, pedagogical, and content knowledge.

In the context of artificial intelligence, the relevance of TPACK becomes even more pronounced. Educators must not only understand how AI technologies function but also how to integrate them pedagogically to support meaningful learning. For example, the use of an educational chatbot is ineffective if it is not aligned with curricular objectives and learner needs.

An important dimension of this model is the development of AI literacy, which includes understanding algorithmic limitations, recognizing bias, and critically evaluating AI-generated content. Without these competencies, there is a risk of superficial or inappropriate use of technology.

Empirical studies suggest that educators who effectively integrate technology into teaching practices have a significantly greater impact on student performance (Koehler et al. 2013). Therefore, the TPACK model serves both as a theoretical construct and as a practical framework for teacher development.

2.2.3 Constructive Alignment (Biggs)

Constructive alignment, developed by John Biggs (1996), is a key principle in instructional design. It posits that all components of the learning process—learning objectives, teaching activities, and assessment methods—must be aligned to ensure coherence and effectiveness.

In the context of AI, this principle gains additional relevance. For instance, if the objective is to develop critical thinking skills, the use of AI tools that automatically generate answers may be counterproductive. Instead, AI can be leveraged to create complex problem scenarios or to facilitate discussion and reflection.

Assessment is another critical dimension. AI systems can automate grading and provide immediate feedback; however, these processes must remain aligned with intended learning outcomes. Superficial assessments may encourage rote learning, whereas authentic assessments supported by AI can promote deeper understanding.

Research indicates that constructive alignment is a key determinant of learning quality (Biggs & Tang 2011). Consequently, the integration of AI in education must adhere to these principles to be effective.

2.3 Definition and delimitation of key concepts

To ensure conceptual clarity, it is essential to define the key terms used in this study. Adaptive learning refers to the use of algorithms to adjust content and pacing based on individual learner needs, often implemented through Intelligent Tutoring Systems that provide personalized feedback and dynamic learning pathways.

Intelligent tutoring systems are software applications designed to simulate interaction with a human tutor by offering explanations, exercises, and feedback. These systems rely on cognitive models and can adapt instructional strategies based on user responses (Woolf 2010).

Learning analytics involves the collection and analysis of data related to the learning process, with the aim of improving educational outcomes. Such data may include time spent on tasks, interaction patterns, and assessment performance.

Generative AI refers to models capable of producing original content, such as text, images, or code. In educational contexts, these tools can support writing, summarization, and feedback, but they also raise concerns regarding authenticity and academic integrity.

A critical distinction must also be made between digitalization and digital transformation. Digitalization involves the use of technology to automate existing processes, whereas digital transformation implies a fundamental change in how educational systems operate.

This conceptual clarification is essential for ensuring analytical rigor and avoiding ambiguity in the interpretation of findings.

3 Methodology

This study adopts a systematic literature review approach, complemented by a narrative analysis, in order to rigorously synthesize relevant contributions on the integration of artificial intelligence in education. The choice of this design is justified by the need for a comprehensive perspective on a rapidly evolving field, as well as by existing research highlighting the value of systematic reviews in mapping AI applications in educational contexts (Zawacki-Richter et al. 2019). At the same time, this approach enables the integration of technological and pedagogical dimensions, particularly in relation to self-regulated learning models.

The selection of studies was based on explicit inclusion and exclusion criteria. Only peer-reviewed academic publications addressing the use of artificial intelligence in educational contexts were included, with a focus on applications, theoretical frameworks, and pedagogical implications. Studies lacking direct educational relevance, duplicate publications, or those with insufficient methodological rigor were excluded. This process resulted in a coherent body of literature, aligned with key research directions identified in recent studies on AI in education (Zawacki-Richter et al. 2019).

Data analysis was conducted through thematic analysis and narrative synthesis, aiming to identify major research trends, patterns of AI use, and their implications for learning processes. In particular, the interpretation of findings was guided by the perspective of self-regulated learning, emphasizing how AI-based tools can support metacognitive processes, adaptive feedback, and scaffolding strategies (Mollick & Mollick 2023). Where available, quantitative findings were also considered to support the conclusions.

Through this methodological approach, the study provides a theoretically grounded and critically informed synthesis of the role of artificial intelligence in transforming the educational process.

4 AI Applications and technologies in education: perspectives for innovation and educational leadership

4.1 Adaptive systems and intelligent tutoring systems

Adaptive systems and intelligent tutoring systems represent some of the most significant applications of artificial intelligence in education, with considerable potential to transform teaching and learning processes. These systems are designed to provide personalized learning experiences by dynamically adjusting content and pacing according to learners' individual needs, based on the analysis of performance and behavioral data. From an educational leadership perspective, such technologies support the transition toward student-centered and data-driven learning models (Zawacki-Richter et al. 2019; Crompton & Burke 2023).

Examples such as Duolingo Max, Squirrel AI, and Khan Academy illustrate how algorithms can identify knowledge gaps and generate adaptive learning pathways. Empirical studies indicate that the use of personalized learning systems can lead to significant improvements in academic performance (Pane et al., 2015). Furthermore, recent literature emphasizes that the effectiveness of these systems depends on the quality of algorithmic models and their integration into appropriate pedagogical contexts (Crompton & Burke 2023).

However, the implementation of these technologies raises important challenges, including risks related to algorithmic bias and the ethical use of educational data. These concerns highlight the need for institutional strategies that integrate technological, pedagogical, and ethical dimensions.

4.2 Generative AI and Large Language Models (LLMs)

Generative artificial intelligence, particularly large language models (LLMs), represents a paradigm shift in education, offering extensive opportunities for the creation and personalization of educational content. These technologies can support processes such as writing, explaining complex concepts, and providing adaptive feedback, thereby contributing to the development of self-regulated learning (Mollick & Mollick 2023).

In educational contexts, LLMs are used by both students and educators for tasks such as summarizing information, generating questions, and developing instructional materials. Recent studies suggest that these tools can enhance metacognitive processes and facilitate access to educational resources (Kasneci et al. 2023; Chan & Hu 2023).

Nevertheless, the use of generative AI involves significant risks. These include variability in the accuracy of generated information, potential issues related to plagiarism, and the possible decline of critical thinking skills. Recent research underscores the need for clear ethical frameworks and the development of critical evaluation skills for AI-generated content (Baidoo-Anu & Ansah 2023; Kasneci et al. 2023).

4.3 Learning Analytics

Learning analytics is an emerging field that leverages educational data to improve teaching and learning processes. These tools enable the identification of behavioral patterns and factors influencing academic performance, thereby supporting data-informed decision-making in education (Jivet et al. 2018).

One of the key advantages of learning analytics is its capacity to identify students at risk of dropout and to enable early interventions. This is particularly relevant in contemporary educational contexts, where institutions increasingly focus on retention and student success. Research indicates that the use of educational data can support the development of effective and personalized intervention strategies (Ifenthaler & Yau 2020).

However, the use of such technologies raises important concerns related to privacy, data security, and transparency. The implementation of clear governance policies and compliance with data protection regulations are essential for the responsible use of learning analytics.

4.4 Collaborative platforms and emerging technologies

Digital collaborative platforms, such as Google Classroom, Microsoft Teams, and Padlet, have become essential components of the contemporary educational ecosystem. The integration of AI functionalities into these platforms facilitates task automation, personalized learning, and enhanced collaboration among users.

At the same time, emerging technologies such as augmented reality (AR) and virtual reality (VR) provide new opportunities for creating immersive learning experiences. These technologies can support the understanding of complex concepts and increase student engagement (Radianti et al. 2020).

Gamification represents another relevant direction, contributing to increased motivation and engagement in the learning process. Studies show that the integration of game-based elements in digital environments can improve information retention and user satisfaction (Dichev & Dicheva 2017).

Despite these benefits, the implementation of such technologies involves challenges related to infrastructure, digital competencies, and sustainability. Their effective integration requires a strategic approach that prioritizes pedagogical objectives and user needs, rather than focusing solely on technological adoption.

To synthesize the principal categories of AI-enhanced educational technologies discussed throughout this chapter, Table 1 presents a comparative overview of their educational functions, potential benefits and associated governance or implementation challenges.

Table 1. Table captions should be placed above the tables.

AI Application / Technology	Main Educational Function	Potential Benefits	Governance and Implementation Challenges
Adaptive Learning Systems & Intelligent Tutoring Systems	Personalized instruction and adaptive feedback	Improved learner support; individualized learning pathways	Algorithmic bias; ethical use of learner data
Generative AI and Large Language Models (LLMs)	Content generation and academic assistance	Enhanced creativity; adaptive feedback; learning support	Academic integrity risks; misinformation; overreliance on AI
Learning Analytics	Monitoring learner behavior and predicting performance	Early intervention; personalized support; data-informed decisions	Privacy concerns; data governance; transparency issues
Collaborative Platforms with AI Functionalities	Digital collaboration and task automation	Increased engagement; communication efficiency; collaborative learning	Infrastructure dependency; digital competence gaps
Emerging Technologies (AR/VR, Gamification)	Immersive and interactive learning experiences	Increased motivation; improved conceptual understanding	High implementation costs; sustainability and accessibility challenges

The comparative perspective presented in Table 1 demonstrates that AI-enhanced educational technologies generate both pedagogical opportunities and governance-related challenges. Consequently, sustainable educational innovation depends not only on technological adoption, but also on the institutional capacity to integrate these technologies responsibly, ethically and strategically.

5 Benefits of AI integration in education

The integration of artificial intelligence in education brings a range of significant benefits that have the potential to fundamentally reshape teaching and learning processes. One of the most prominent advantages is the personalization of the learning experience. AI enables the adaptation of content, pacing, and difficulty level according to individual learner needs, which can lead to improved academic outcomes and a more engaging learning environment (Zawacki-Richter et al. 2019; Crompton & Burke 2023).

Another major benefit lies in supporting self-regulated learning. Through real-time feedback and continuous monitoring, learners can develop greater awareness of their own learning processes and enhance their metacognitive skills. This is particularly relevant in contemporary educational contexts, where lifelong learning has become essential. AI-driven tools can facilitate goal setting, progress tracking, and adaptive feedback, all of which are key components of self-regulated learning (Mollick & Mollick 2023).

AI also contributes to the efficiency of teaching practices. By automating administrative tasks and aspects of assessment, such as grading and feedback generation, educators can allocate more time to high-value activities, including mentoring, instructional design, and individualized student support. This shift has important implications for educational leadership, as it supports more strategic and student-centered teaching approaches (Crompton & Burke 2023).

In addition, AI has the potential to enhance accessibility and inclusion in education. Tools such as text-to-speech systems, automatic translation, and adaptive interfaces can support learners with diverse needs, including those with disabilities or language barriers. These technologies can help reduce educational inequalities and broaden access to learning opportunities for diverse populations (Kasneci et al. 2023).

Overall, while the integration of AI introduces certain challenges, its benefits in terms of personalization, learner autonomy, instructional efficiency, and inclusivity position it as a key driver of innovation in education.

6 Challenges and Risks

Despite its significant benefits, the integration of artificial intelligence in education is accompanied by a range of critical challenges and risks that require careful consideration. One of the most prominent issues is digital equity. Unequal access to technological infrastructure, devices, and digital competencies can exacerbate existing disparities between socio-economic groups and geographic regions. As a result, the implementation of AI-driven solutions may unintentionally reinforce educational inequalities rather than mitigate them (Zawacki-Richter et al. 2019).

Ethical concerns also play a central role in the adoption of AI in education. Issues related to data privacy, algorithmic bias, and lack of transparency must be addressed with rigor. AI systems rely on large datasets, often containing sensitive personal information, raising concerns about data protection and compliance with regulatory frameworks. Furthermore, algorithmic bias may lead to discriminatory outcomes, particularly if training data are unrepresentative or flawed. The so-called "black-box" nature of many AI systems further complicates accountability and trust (Kasneci et al. 2023; Crompton & Burke 2023).

Another significant risk is technological dependency. Excessive reliance on AI tools may reduce opportunities for the development of critical thinking, problem-solving, and creativity. If learners increasingly depend on automated systems for answers and feedback, there is a risk that essential cognitive and metacognitive skills may be underdeveloped. This concern is particularly relevant in the context of generative AI, where the ease of content production may discourage deeper engagement with learning materials (Baidoo-Anu & Ansah 2023).

In addition, challenges related to the professional development of educators must be acknowledged. Many teachers may lack the necessary competencies to effectively integrate AI into their pedagogical practices, highlighting the need for continuous training and support. At the same time, there is a lack of longitudinal research examining the

long-term impact of AI on learning outcomes, which limits the ability to draw definitive conclusions about its effectiveness and sustainability.

Addressing these challenges requires a balanced and strategic approach that combines technological innovation with ethical responsibility, pedagogical soundness, and inclusive policy frameworks.

7 Governance Frameworks and Policy Implications

To ensure the responsible and effective integration of artificial intelligence in education, the development of clear and coherent governance frameworks is essential. International organizations such as UNESCO and the European Union have proposed guidelines and strategic frameworks aimed at promoting the ethical use of AI in educational contexts. These frameworks emphasize key principles including transparency, accountability, fairness, and inclusivity, which are critical for building trust and ensuring equitable outcomes.

At the institutional level, the adoption of AI requires a systematic assessment of organizational readiness, including infrastructure, digital competencies, and policy alignment. Educational institutions must invest in the continuous professional development of educators, equipping them with the skills necessary to critically and effectively integrate AI into teaching practices. Furthermore, governance approaches should encourage the active involvement of multiple stakeholders, including educators, students, policymakers, and technology developers, in the decision-making process. Such participatory approaches can support more context-sensitive and sustainable implementations of AI in education (Crompton & Burke 2023).

8 Future research directions

Future research should prioritize longitudinal studies and investigations across diverse educational contexts in order to better understand the long-term impact of artificial intelligence on learning outcomes. Much of the existing literature is based on short-term or context-specific studies, which limits the generalizability of findings.

There is also a need for the development of robust evaluation frameworks and impact assessment tools that can measure not only academic performance but also broader dimensions such as critical thinking, learner autonomy, and equity. In parallel, further research is required to advance ethical frameworks that address emerging challenges related to data use, algorithmic bias, and accountability.

Another key area for future investigation is the transferability and scalability of AI-based solutions across different educational systems and contexts. Ensuring that technologies can be effectively adapted to diverse cultural, linguistic, and institutional environments is essential for their sustainable adoption. These directions highlight the importance of interdisciplinary research that bridges technological innovation with pedagogical and social considerations.

9 Conclusions and implications

The transformation of education through artificial intelligence represents both a significant opportunity and a complex challenge. The analysis presented in this study highlights the multifaceted nature of AI integration, encompassing substantial benefits alongside notable risks and limitations.

Artificial intelligence has the potential to support self-regulated learning, personalize educational experiences, and enhance the efficiency of teaching and learning processes. At the same time, its implementation must be approached with caution, ensuring alignment with pedagogical objectives and ethical standards. The findings underscore the importance of maintaining a balanced approach, in which technological innovation is complemented by critical reflection and responsible governance.

Importantly, the role of the teacher remains central within AI-enhanced educational environments. Rather than replacing educators, AI should be understood as a tool that supports and augments human expertise. Effective integration depends on the ability of educators and institutions to harness these technologies in ways that enhance, rather than diminish, the quality and integrity of the educational process.

References

1. Biggs, J. Enhancing teaching through constructive alignment. High Educ 32, 347–364 (1996). https://doi.org/10.1007/BF00138871
2. Biggs, J., Tang, C.: Teaching for quality learning at university, 5e. McGraw-Hill Education, (2022)
3. Bond, M., Marín, V.I., Dolch, C. et al. Digital transformation in German higher education: student and teacher perceptions and usage of digital media. Int J Educ Technol High Educ 15, 48 (2018). https://doi.org/10.1186/s41239-018-0130-1
4. Braun, V., Clarke, V.: Using thematic analysis in psychology. Qual. Res. Psychol. 3(2), 77–101 (2006). https://doi.org/10.1191/1478088706qp063oa
5. Hussin, A.A.: Education 4.0 made simple: Ideas for teaching. Int. J. Educ. Lit. Stud. 6(3), 92–98 (2018). DOI: 10.7575/aiac.ijels.v.6n.3p.92
6. Ifenthaler, D., Yau, J.Y.K.: Utilising learning analytics to support study success in higher education: A systematic review. Educ. Technol. Res. Dev. 68(4), 1961–1990 (2020). DOI: 10.1007/s11423-020-09788-z
7. Jivet, I., Scheffel, M., Drachsler, H., Specht, M.: Awareness is not enough: Pitfalls of learning analytics dashboards in educational practice. In: Lecture Notes in Computer Science, vol. 10474, pp. 82–96. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-66610-5_7
8. Kasneci, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., et al.: ChatGPT for good? On opportunities and challenges of large language models for education. Learn. Individ. Differ. 103, 102274 (2023). https://doi.org/10.1016/j.lindif.2023.102274
9. Kitchenham, B.: Procedures for performing systematic reviews. Keele University Technical Report TR/SE-0401 (2004)
10. Koehler, M.J., Mishra, P., Cain, W.: What is technological pedagogical content knowledge (TPACK)? J. Educ. 193(3), 13–19 (2013). https://doi.org/10.1177/002205741319300303

11. Luckin, R., Holmes, W., Griffiths, M., Forcier, L.B.: Intelligence unleashed: An argument for AI in education. Pearson Education, London (2016)
12. Mollick, E.R., Mollick, L.: Using AI to implement effective teaching strategies in classrooms: Five strategies, including prompts. SSRN Electronic Journal (2023). http://dx.doi.org/10.2139/ssrn.4391243
13. Pane, J.F., Steiner, E.D., Baird, M.D., Hamilton, L.S.: Continued progress: Promising evidence on personalized learning. RAND Corporation, Santa Monica (2015)
14. Radianti, J., Majchrzak, T.A., Fromm, J., Wohlgenannt, I.: A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. Comput. Educ. 147, 103778 (2020). https://doi.org/10.1016/j.compedu.2019.103778
15. Selwyn, N.: Education and technology: Key issues and debates, 2nd edn. Bloomsbury Academic, London (2016)
16. UNESCO: AI and education: Guidance for policy-makers. UNESCO Publishing, Paris (2021)
17. Zimmerman, B.J.: Becoming a self-regulated learner: An overview. Theory Pract. 41(2), 64–70 (2002).
18. Zawacki-Richter, O., Marín, V.I., Bond, M. et al. Systematic review of research on artificial intelligence applications in higher education – where are the educators?.Int J Educ Technol High Educ 16, 39 (2019). https://doi.org/10.1186/s41239-019-0171-0