The use of artificial intelligence in educational and scientific practice: the literature review

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Abstract

The rapid integration of artificial intelligence (AI) into educational and scientific domains represents a paradigmatic shift in how knowledge is created, disseminated, and applied. This comprehensive literature review synthesizes recent developments (2018-2025) in AI applications across education and scientific research, with particular emphasis on emerging trends in generative AI, explainable AI (XAI), and ethical frameworks. Through systematic analysis of international literature, we identify cross-cutting themes including personalized adaptive learning, methodological innovations in scientific discovery, and critical ethical challenges. The review reveals that while AI technologies – particularly large language models (LLMs) and intelligent tutoring systems (ITS) – demonstrate transformative potential for personalized education and accelerated scientific discovery, their implementation raises significant concerns regarding algorithmic bias, data privacy, and educational equity. We examine the evolution from AI-directed to AI-empowered learning paradigms, the emergence of multi-agent systems for educational personalization, and the critical role of explainable AI in building trust and accountability. Our analysis highlights persistent gaps between theoretical frameworks and practical implementation, particularly in under-resourced educational contexts. The paper concludes by proposing a research agenda that prioritizes ethical AI deployment, interdisciplinary collaboration, and the development of context-responsive applications that balance technological innovation with human-centered pedagogical values.

Keywords

artificial intelligence in education, AI ethics in learning, explainable AI in education, personalized adaptive learning, generative AI applications, algorithmic bias in AIED, educational equity and AI, human-AI collaboration in teaching, AI-driven scientific discovery, multi-agent systems in education, ethical AI frameworks, AI literacy for educators, digital divide in AI-enhanced learning, future of teaching and learning with AI

1. Introduction

The technological revolution currently transforming global society extends profoundly into education and science, with artificial intelligence (AI) playing an increasingly central role in reshaping traditional paradigms of teaching, learning, and research [1, 2, 3, 4, 5, 6]. The AI equipment market, valued at 279.22 billion USD in 2024, is projected to grow by 36% annually through 2030 [7], reflecting the technology's expanding influence across all sectors of human activity.

In education, AI algorithms and educational robots have become integral components of learning management systems, providing sophisticated support for diverse educational activities [8, 9, 10]. Recent advances in generative AI, particularly large language models like GPT-4, have accelerated this transformation, enabling unprecedented levels of personalization and adaptive learning [11, 12, 13]. Similarly, in scientific research, AI methodologies are revolutionizing hypothesis generation, experimental design, and data analysis, creating new paradigms for scientific discovery [14, 1].

This literature review critically examines the current state of AI integration in educational and scientific practice, synthesizing findings from international research conducted between 2018 and

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2025. We analyze the contributions of leading researchers while identifying persistent challenges and emerging opportunities in this rapidly evolving field.

2. Analysis of recent research and publications

2.1. International perspectives on AI in education

Among foreign researchers who have significantly contributed to understanding AI's role in education, several scholars have provided foundational insights that continue to shape the field.

Neil Selwyn's critical analysis of educational technologies has been particularly influential in examining both opportunities and risks. In "Should robots replace teachers? AI and the future of education" [15], Selwyn interrogates the fundamental assumptions underlying AI integration in education, arguing that while AI can enhance certain educational functions – assessment, personalization, administrative efficiency – it cannot replicate the essential human dimensions of teaching: emotional connection, pedagogical intuition, and ethical judgment. His recent work with colleagues on generative AI [16] examines the explosive growth of AI tools, highlighting critical ethical challenges including copyright infringement, algorithmic bias, and the spread of misinformation in educational contexts.

Rose Luckin's research provides a complementary perspective, focusing on the practical implementation of AI to enhance learning outcomes. Her seminal work "Machine Learning and Human Intelligence: The Future of Education in the 21st Century" [17] establishes a framework for understanding how AI can augment rather than replace human intelligence in educational settings. Luckin et al. [18] demonstrate that AI's greatest potential lies in its ability to personalize educational experiences, tailoring content, pacing, and assessment to individual learner needs. This personalization extends beyond simple adaptation; it encompasses the creation of individual learning trajectories that respond dynamically to cognitive abilities, learning styles, and emotional states.

The critical importance of ethical AI implementation emerges as a central theme across recent literature. Khosravi et al. [19] introduce the XAI-ED framework, addressing the unique requirements for explainability in educational contexts. Their work identifies six key aspects: stakeholder diversity, pedagogical benefits, explanation presentation methods, model transparency, human-centered design, and potential pitfalls. This framework has become essential for building trust in AI-powered educational systems.

Recent empirical studies have validated the effectiveness of AI-enhanced learning [20, 21]. Kestin et al. [22] report results from a randomized controlled trial demonstrating that students using AI tutors learn significantly more in less time compared to traditional active learning classes, while also reporting higher engagement and motivation. However, these benefits are not uniformly distributed. Matos et al. [23] systematic review of 45 studies reveals that while ChatGPT and similar tools show strong performance in theoretical knowledge delivery, challenges persist regarding data privacy, algorithmic bias, and the need for specialized educator training.

The paradigm shift in AI's educational role is comprehensively analyzed by Ouyang and Jiao [2], who identify three evolutionary paradigms: AI-directed (learner-as-recipient), AI-supported (learner-as-collaborator), and AI-empowered (learner-as-leader). This framework captures the field's trajectory toward greater learner agency and personalized, data-driven education.

2.2. AI in scientific research methodologies

The integration of AI into scientific research represents a fundamental transformation in how knowledge is generated and validated [24]. Wang et al. [1] provide a comprehensive overview of how AI augments and accelerates research through self-supervised learning, geometric deep learning, and generative methods. These technologies enable scientists to generate hypotheses, design experiments, and interpret complex datasets at unprecedented scales.

Particularly noteworthy is the development of automated research systems. Luo et al. [14] introduce BioResearcher, an end-to-end automated system for biomedical research that employs a modular multi-agent architecture. This system achieves an average execution success rate of 63.07% across previously unmet research objectives, demonstrating AI's potential to independently conduct scientific investigations. Similarly, Akujuobi et al. [25] present THiGER, a temporal graph-based approach for hypothesis generation that leverages active curriculum learning to predict future entity relationships in scientific literature.

The application of generative AI in scientific discovery has shown particular promise. Das [26] review advances in drug discovery and protein design, highlighting how variational autoencoders (VAEs), generative adversarial networks (GANs), and diffusion models enable inverse molecular design and de novo protein engineering. These methods have already produced AI-designed molecules that have progressed to clinical validation, marking a significant milestone in AI-driven scientific innovation.

2.3. Developments in Ukraine, Poland, and Eastern Europe

Ukrainian scientists have made significant contributions to understanding AI's educational applications within specific regional contexts. Lobanova et al. [27], Fadieieva [28], Riabko and Vakaliuk [29] explores the prospects for AI integration in Ukrainian education, analyzing successful implementations of personalized learning, automated assessment, and adaptive learning environments. The work of Kolomiets and Kushnir [30] addresses two fundamental aspects: AI's opportunities and threats in teacher training, and its impact on research organization and conduct. They emphasize that while AI has revolutionary potential for the scientific community, this transformation brings ethical and practical challenges that require careful navigation.

Androshchuk and Maluga [31] provide a comprehensive analysis of AI trends in Ukrainian higher education, examining both international and domestic experiences. Their research highlights the urgent need to rethink educational approaches, balancing AI's advantages with concerns about academic integrity and educational quality. Panukhnyk [32] offers a unique perspective on virtual reality as a newly organized social space that encourages systematic changes in educational processes and student research activities, arguing that AI serves as a modern pedagogical mechanism with important conceptual and methodological significance.

Polish researchers have contributed valuable insights into competency development and practical implementation strategies. Symela and Stępnikowski [33] analyze the workforce challenges associated with AI development in Poland, noting that up to 40% of working hours may be automated by 2030. They propose the "HUN" (Hybrid & Unconventional) competency development model to address technological unemployment through adaptive education. Recent studies by Kopczyński [34] examine AI integration in Polish universities, with particular attention to chatbot applications for student support and the ethical dimensions of personalized learning systems.

3. Emerging themes and critical issues

3.1. Explainable AI and trust in educational systems

The emergence of explainable AI (XAI) represents a critical development in educational technology. Liu et al. [35] demonstrate how combining SHAP and LIME methods provides both global feature importance and individual decision insights, essential for maintaining transparency in educational assessment. Furze et al. [36] report on implementing the AI Assessment Scale (AIAS), showing significant reductions in academic misconduct while enhancing student engagement with AI technology.

The importance of causability – users' ability to understand AI's cause-effect linkages – emerges as a key factor in building trust. Lünich and Keller [37] experimental study reveals that decision tree simplicity positively affects fairness perceptions through enhanced causability, though institutional trust moderates these relationships. This finding has profound implications for designing transparent machine learning models in educational settings.

3.2. Ethical frameworks and regulatory developments

The rapid deployment of AI in education has outpaced regulatory frameworks, creating urgent needs for governance structures. The European Union's AI Act, analyzed by Saarela et al. [38], introduces critical provisions for education, including prohibitions on emotion inference AI and requirements for transparency in high-stakes decision-making systems. This regulatory approach reflects growing consensus that AI in education must balance innovation with protection of student rights and educational values.

Ersoy [39] proposes a comprehensive framework for inclusive AI transformation in education, emphasizing data-driven diversity, ethical design principles, transparency, accountability, and continuous improvement. The framework addresses critical issues of bias and inequity that can be amplified by AI systems if not carefully managed. Marín et al. [40] empirical study of 890 students and 162 faculty members reveals widespread concerns about data privacy (51.2% of faculty) and system transparency (61.1% of faculty), highlighting the gap between AI capabilities and stakeholder trust.

The challenge of algorithmic bias receives particular attention in recent literature. Idowu [41] systematic review identifies common debiasing strategies including sample weight adjustment, fairness through unawareness, and adversarial learning. Significantly, most studies find no strict tradeoff between fairness and accuracy, suggesting that ethical AI implementation need not compromise educational effectiveness.

3.3. Generative AI and learning paradigms

The advent of generative AI, particularly large language models, has fundamentally altered educational possibilities [42, 43]. Valdivieso and González [44] mixed-methods study in El Salvador reveals how socioeconomic disparities affect access to and use of generative AI tools, with lower-income students primarily using smartphones and free tools while higher-income peers access premium features on laptops. This digital divide threatens to exacerbate existing educational inequalities unless addressed through institutional policies and support structures.

Tan et al. [45] examination of student perceptions regarding generative AI regulations reveals complex relationships between guideline understanding, compliance, and academic integrity. Their theory of planned behavior model shows that while understanding promotes compliance, perceived restrictiveness and increased AI experience can negatively impact honest declaration of AI use. This finding underscores the need for balanced regulatory approaches that promote responsible use without stifling innovation.

Multi-agent systems represent a particularly promising development. Vaccaro et al. [13] demonstrate how GPT-4-based frameworks can dynamically adapt science content for middle school students, with pilot studies showing increased preference for personalized texts. Hedi et al. [46] AIA-PAL framework employs LangGraph and CrewAI to provide real-time monitoring and specialized pedagogical support through collaborative agent networks, addressing limitations in current intelligent tutoring systems.

3.4. Challenges in implementation and equity

Despite technological advances, significant challenges persist in AI implementation. Gouveia et al. [47] systematic review identifies key barriers including lack of human interaction, need for teacher training, and algorithmic inaccuracies. The digital divide remains particularly acute in developing regions. Isotani et al. [48] propose "AIED Unplugged" – an approach to creating AI-based educational technologies that function without stable internet or advanced infrastructure. Their implementation in Brazil positively impacted over 500,000 students across 7,000 schools, demonstrating the feasibility of context-appropriate AI solutions.

Teacher preparation emerges as a critical factor. Mouta et al. [49] educational design research reveals that comprehensive professional development must address not only technical skills but also ethical considerations and pedagogical integration. Tenberga and Daniela [50] development of AI literacy self-assessment tools shows that while AI competencies overlap with digital skills in some areas, they form distinct categories requiring focused attention.

The intersection of AI with disability and special education presents both opportunities and challenges. Kohnke and Zaugg [51] demonstrate how AI can promote equity in STEM education for students with disabilities through personalized learning and improved accessibility. Farhah et al. [52] ALGA-Ed framework leverages generative AI to create customized multimodal content for diverse disability profiles, showing improvements in participation, retention, and learning outcomes.

4. Key unresolved issues requiring further investigation

Our analysis reveals several critical areas requiring sustained research attention:

1. *Ethical dimensions and accountability*: How can we develop algorithmic accountability mechanisms that prevent bias while maintaining educational effectiveness? The literature reveals persistent tensions between automated decision-making and human oversight. Who bears responsibility for pedagogical errors made by AI systems? How do we balance efficiency gains with preservation of human agency in education?
2. *Teacher autonomy and professional identity*: The active implementation of AI fundamentally alters teachers' roles, yet research inadequately addresses how educators navigate this transformation. How does AI affect teachers' professional autonomy in assessment, curriculum design, and pedagogical decision-making? What new competencies must teachers develop to effectively collaborate with AI systems while maintaining their unique human contributions?
3. *Long-term cognitive and social development*: Current research predominantly examines short-term learning outcomes, leaving critical questions about AI's long-term impacts unanswered. Can partial replacement of human interaction with AI agents affect students' development of empathy, critical thinking, and communication skills? How does AI-mediated learning influence students' metacognitive abilities and self-regulated learning strategies?
4. *Global equity and access*: The digital divide threatens to transform AI from an equalizing force into a mechanism for perpetuating inequality. How can we ensure equitable access to AI-enhanced education across socioeconomic, geographic, and cultural boundaries? What adaptations are necessary for AI systems to function effectively in resource-constrained environments?
5. *Academic integrity in the AI era*: Generative AI fundamentally challenges traditional concepts of academic integrity. How do we redefine plagiarism and original work when AI can generate sophisticated academic content? Should assessment methods evolve to embrace AI collaboration rather than prohibit it? How do we balance the benefits of AI-assisted learning with maintaining authentic skill development?
6. *Methodological rigor in educational AI research*: What metrics accurately capture AI's multifaceted impact on education? How can we conduct rigorous comparative studies when AI systems evolve rapidly? What longitudinal research designs can assess AI's cumulative effects on educational and career trajectories?
7. *Epistemological implications for scientific knowledge*: AI's role in scientific research raises fundamental questions about the nature of knowledge creation. How does AI-generated hypothesis formation affect scientific epistemology? What validation frameworks ensure AI-derived scientific conclusions remain transparent and reproducible? How do we maintain scientific rigor when AI systems operate as "black boxes"?

5. Future directions and recommendations

Drawing on the comprehensive analysis, we identify a coordinated agenda of research priorities alongside practical steps for implementation.

Research should first focus on longitudinal impact, with multi-year cohort studies that track students' cognitive, social, and emotional development across different AI-enhanced learning conditions. These studies must extend beyond conventional achievement metrics to capture creativity, critical thinking, and interpersonal skills, and they should use mixed methods to illuminate mechanisms of change and distributional effects across learner subgroups.

A second priority is context-responsive AI development. Applications should be designed and evaluated for diverse educational settings, particularly in low-resource environments. This includes offline-capable tools that do not depend on constant connectivity and systems that align with local pedagogical traditions while responsibly leveraging technological capabilities.

Third, research should examine hybrid human–AI pedagogical models to determine optimal divisions of labor. Work is needed to identify which instructional functions are best supported or automated by AI and which require distinctly human expertise, as well as to assess impacts on teaching practice, student engagement, and learning equity.

Finally, the field should move from ethical principles to implementation. This entails developing usable instruments for detecting and mitigating algorithmic bias, creating accountability mechanisms and governance protocols appropriate to education systems, and evaluating the feasibility and effectiveness of these approaches in real settings.

Translating these priorities into practice requires action by multiple stakeholders. Educational institutions should introduce comprehensive AI literacy for students, teachers, administrators, and parents; establish ethics committees to oversee adoption and respond to emerging issues; promulgate transparent policies that balance innovation with academic integrity; and invest in infrastructure that ensures equitable access to AI tools for all learners.

Policymakers should develop adaptive regulatory frameworks that can evolve with technological change; mandate auditing and transparency for educational AI systems; fund research on long-term impacts and equity implications; and support professional development to prepare educators for AI-enhanced teaching.

Technology developers should prioritize explainability and transparency in system design; engage educators and students as co-designers rather than passive end users; build culturally responsive systems that respect diverse learning traditions; and implement robust privacy protections rooted in data minimization.

Researchers should adopt interdisciplinary approaches that integrate technical, pedagogical, and ethical perspectives; create standardized metrics for assessing AI's educational impact; conduct comparative studies across cultural and socioeconomic contexts; and investigate how AI interacts with other emerging technologies in education. Together, these steps chart a practical path toward effective, equitable, and accountable use of AI in learning environments.

6. Conclusion

The integration of artificial intelligence into educational and scientific practice represents both unprecedented opportunity and significant challenge. Our comprehensive review reveals a field characterized by rapid technological innovation, evolving pedagogical paradigms, and persistent ethical concerns. While AI demonstrates clear potential to personalize learning, accelerate scientific discovery, and democratize access to knowledge, its implementation raises fundamental questions about human agency, educational equity, and the nature of knowledge itself.

The literature indicates a clear trajectory from AI as a supplementary tool toward AI as an integral partner in education and research. This evolution demands not passive acceptance but active engagement from all stakeholders to shape AI's role in ways that enhance rather than diminish human potential. The shift from AI-directed to AI-empowered learning paradigms reflects growing recognition that technology's value lies not in replacing human capabilities but in augmenting them.

Critical challenges persist, particularly regarding algorithmic bias, data privacy, and the digital divide. These are not merely technical problems but fundamental issues of educational justice that require sustained attention from researchers, practitioners, and policymakers. The development of explainable AI and ethical frameworks represents progress, but significant gaps remain between theoretical frameworks and practical implementation.

Looking forward, the field requires more nuanced understanding of AI's long-term impacts on cognitive and social development, more robust methodologies for assessing educational outcomes, and more inclusive approaches to technology deployment. The experiences of early adopters, particularly in resource-constrained environments, provide valuable lessons for scaling AI-enhanced education globally.

Ultimately, the question is not whether AI will transform education and science – that transformation is already underway – but how we can guide this transformation to serve humanity's highest aspirations. This requires maintaining a critical perspective that neither uncritically embraces technological solutions nor reflexively resists innovation. Instead, we must cultivate what might be called "critical technological wisdom" – the ability to discern when, how, and why to deploy AI in service of authentic human development.

The path forward demands unprecedented collaboration across disciplines, cultures, and sectors. Computer scientists must work with educators, ethicists with engineers, and policymakers with practitioners. Only through such collaboration can we realize AI's potential while safeguarding the essentially human dimensions of learning and discovery that no algorithm can replace.

As we advance into an AI-enhanced future, we must remember that education's ultimate purpose transcends efficiency and optimization. It encompasses the cultivation of wisdom, creativity, empathy, and ethical reasoning – qualities that remain fundamentally human. The challenge and opportunity before us is to harness AI's power in ways that amplify these human qualities rather than diminish them, creating educational and scientific ecosystems that are both more powerful and more humane.

Declaration on Generative AI

The authors used Scopus AI to find the additional references, and the gpt-5-high-new-system-prompt model to polish sentences.

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