EDITORIAL

AI and the Evolution of Medical Education: Speed, Scale, and Stewardship

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Abstract

Medical education has evolved through successive accelerants—from writing and the printing press to the internet—each expanding the speed, reach, and fidelity of learning. This editorial argues that artificial intelligence (AI) is the next inflection point in that evolutionary arc. We synthesize recent reviews across health professions and propose an educator-led governance roadmap. We also conduct a rapid bibliometric scan (titles containing "AI" and "education") in PubMed and OpenAlex (2023–2025) to illustrate early diffusion dynamics.

Across the literature, near-term opportunities cluster around three domains: 1) personalization at scale via adaptive practice, formative feedback, and multilingual access; 2) workflow augmentation, including generation of learning materials, items, and rubrics; and 3) high-fidelity practice using simulation and conversational agents for clinical reasoning and communication. Evidence for short-term knowledge and skills gains is promising but fragile, as most studies are small, single-site, and of brief duration, and rarely assess downstream competence, equity, or safety. Salient risks include hallucinations and bias, privacy and confidentiality concerns, threats to assessment integrity, and potential erosion of learner agency without careful scaffolding.

Our bibliometric indicator retrieved 419 PubMed records and 1,745 OpenAlex author-affiliation entries, with contributions led by high-income countries yet rapidly emerging across middle- and low-income settings—suggesting a shortening lag from innovation to global uptake. We recommend human-in-the-loop use, transparent disclosure, data safeguards, redesign of assessment processes, faculty capacity-building, and rigorous evaluation with equity and safety endpoints. If aligned with learning science and ethical governance, AI can compress discovery-to-practice cycles and narrow disparities—enhancing, rather than replacing, the human relationships at the heart of medical training.

Keywords (MeSH):

Education, Medical, Artificial Intelligence, Teaching/Methods, Curriculum, Educational Measurement

INTRODUCTION

This issue of Future of Medical Education Journal (FMEJ) is dedicated to the transformative role of artificial intelligence (AI) in medical education. Building on our recent call for papers, which invited contributions on topics ranging from AI-driven teaching and personalized technologies to intelligent tutoring, assessment, and ethics, this special issue aims to highlight both global innovations and critical challenges in the field.

In this editorial, we take a closer look at what the evidence so far tells us about the role of AI in medical education—its advantages, its shortcomings, and the risks that must not be overlooked. We also highlight how the use of AI is spreading rapidly across different parts of the world, not only in high-income countries but also in middle- and low-income settings, where its impact and potential may be especially significant. We also propose a pragmatic framework for responsible adoption—one that emphasizes faculty leadership, ethical safeguards, and rigorous evaluation.

Breakthrough in Human Development

The discovery of AI is one of the most remarkable milestones in the long arc of human development. From a Darwinian perspective, evolution has been shaped by adaptation and natural selection, favouring those with the cognitive, social, and practical skills needed to thrive (1). Homo sapiens has been distinguished from other hominids by its superior cognitive abilities, symbolic thinking, and complex communication. These abilities gave rise to a cumulative culture and a "ratchet effect," where knowledge was not only preserved but also continually refined and developed over generations (2, 3).

In the digital era, this cumulative culture operates through global, always-on infrastructures—creating a "faster ratchet" in which the capture, retrieval, and recombination of knowledge occur at unprecedented speed (4, 5). Milestones in the evolution of education from writing to artificial intelligence are shown in Figure 1.

Human development has been influenced by communication and learning since the days of hunter-gatherer societies, which enabled communities to refine their tools, strategies, and social systems over countless generations (6). Similarely, education has become a purposeful means to accelerate progress, systematically transfer knowledge, foster collaboration, and, more importantly, preserve cultural memory over the course of civilization's development. The creation of schools, and later universities, provided a structured and scalable foundation for literacy, professional training, and the standardization of learning (7).

Later and over centuries, practical teaching has evolved from a unidirectional information transfer

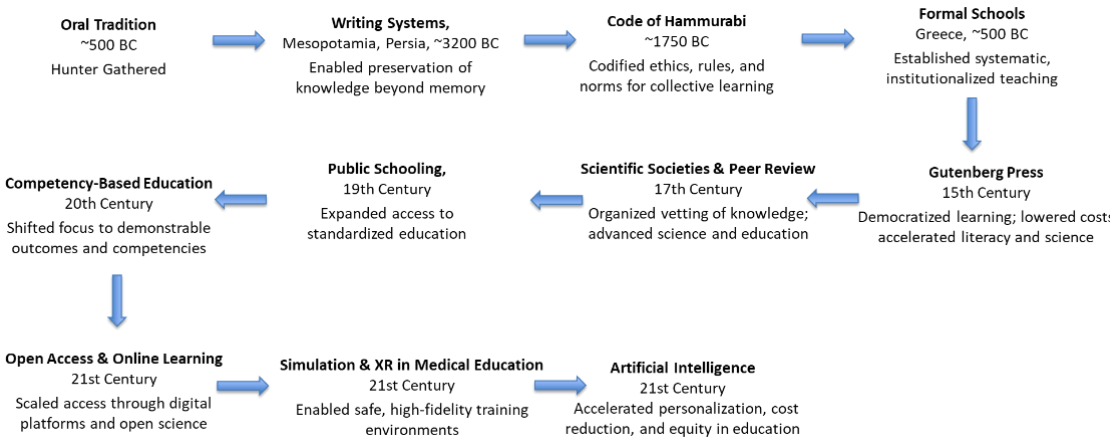

Figure 1. Milestones in the Evolution of Education from Writing to Artificial Intelligence

model to a science of pedagogy. It was supported by insights into cognitive load, retrieval practice, and mastery learning (8-10). Appropriately designed GenAI tools can offload routine tasks (e.g., data cleaning and visualization), freeing cognitive resources for interpretation and transfer—provided that desirable difficulties, retrieval and spacing are preserved (9, 11, 12).

In recent decades, accreditation systems, standardized curricula, and educational innovations such as the objective structured clinical examination (OSCE) and competency-based medical education (CBE) have further improved the quality and outcomes of education (13-15). Technological advances have gradually accelerated the speed, efficiency, and reach of education throughout history. The invention of writing in Mesopotamia, for example, allowed knowledge to survive memory, while the Code of Hammurabi demonstrated how engraved law codified the ethics and norms of collective learning.

The publishing revolution launched by Gutenberg in the 15th century democratized learning, dramatically reducing costs and fueling the growth of literacy, science, and medicine (16). The scientific society and peer review system have institutionalized evidence vetting, while the open science movement and 21st-century preprint platforms have drastically shortened the discovery-to-publication timeline (17).

We observed that computers and the internet transformed accessibility, providing instant global communication and digital knowledge repositories in our lifetime (18). The online resources and distance learning platform, such as learning management systems (LMS), MOOCs, and mobile learning, further accelerated the process. They offered scalable, flexible, and equitable education across borders (19, 20). Crucially, the online turn also professionalized instructional design at scale, normalizing learning analytics and continuous course iteration—an organizational precondition for integrating AI tutors and adaptive assessment (21, 22). Simulation and extended reality (XR) tools in health professions training have taken a significant leap forward, providing high-fidelity, risk-free environments to build competence (23, 24).

Early AI deployments effectively leverage these strengths across various disciplines. Research has shown that AI has been utilized to emphasize personalized learning and facilitate AI-assisted curriculum delivery in the field of dentistry. In pharmacy, conversational agents are being explored for communication scenarios, and in surgery, AI is leveraging robotics and AI for remote coaching—each promising but still evidence-light (25-27).

From a historical perspective, the gap between scientific discovery and real-world adoption has been vast; for example, the discovery and treatment of scurvy is an interesting example. Despite James Lind's 1747 experiment showing citrus fruits prevent disease, it took the Royal Navy more than a century to mandate lemon juice in sailors' rations—a lag that cost countless lives (28, 29).

Today, artificial intelligence represents the next—and perhaps most transformative—inflection point. It personalizes education, leads to rapid knowledge synthesis and automated support systems, all of which reduce the time from discovery to application, lower costs, and expand access, particularly in low-resource settings (30, 31).

Intelligent tutoring systems with adaptive assessments, as well as multilingual platforms, are expected to enhance efficiency and narrow the educational gap between high- and low-income countries. Research has also shown that foundation models extend this potential by enabling mentor-like dialogue, multimodal learning (text–audio–vision), and fine-grained personalization. Despite advantages, surfacing tractable challenges around privacy, bias, and fairness (5, 21).

By compressing the education loop—from

discovery → dissemination → adoption—AI extends the evolutionary arc of education and positions itself as a catalyst for the future of medical training. Real-world success, on the other hand, remains educator led. Studies have shown that faculty preparation, pedagogical adaptation, and change management are more important in creating impact (25, 32-34). It is essential to develop responsive and adaptive ethics education and academic integrity alongside AI with case-based teaching, user-centred frameworks, and practical engagement on consent, bias, privacy, and fairness (35-37). Detection tools for AI-generated text remain fallible and should not be used as a substitute for human judgment (38, 39).

Diffusion of AI in Education: A Preliminary Indicator

To explore the speed at which educational innovations in artificial intelligence (AI) diffuse from high-income to lower-income countries, I conducted a rapid bibliometric scan using PubMed and OpenAlex. We searched article titles containing both AI and education. Although this represents a simplified and limited indicator, it provides an initial lens through which to examine global adoption patterns.

The PubMed search returned 419 articles, almost all published between 2023 and 2025, indicating that AI in education—particularly within public health—is a relatively recent and rapidly expanding field. OpenAlex identified 1745 authors' country affiliation within comparable articles, with most citations originating from the United States (n=384). Nevertheless, author affiliation data (Figure 2) reveal that contributions are not confined to high-income countries. Within just a few years of its conceptual emergence, AI-in-education research has begun to appear in middle- and low-income settings. Table 1 highlights the predominance of high-income countries and the rapid emergence of contributions from middle- and low-income countries. It suggests a shortening of the timeframe for global adoption of this educational innovation Taken together, these findings suggest that AI in education is not only a newly popularized concept but also one that is diffusing globally at an unprecedented pace. The traditional time lag between discovery in high-income countries and adoption in lower-income countries appears to be shortening. This accelerated diffusion underscores both the scalability of digital innovations and the unique potential of AI to narrow global disparities in education. Concordantly, patient-facing applications—plain-language, multilingual education generated by LLMs—show promise for narrowing health- literacy gaps in low-resource settings, contingent on validation for accuracy and relevance (40-43).

Opportunities, Limits, and Risks of AI in Medical Education: A Review Synthesis

Opportunities. Contemporary reviews converge on three near-term gains: (i) Personalization at scale (adaptive practice, formative feedback, and multilingual support),

(ii) Workflow augmentation (drafting learning materials, assessment rubrics, and explanations), and

(iii) High-fidelity practice via simulation and chatbots for history-taking, reasoning, and communication skills.

Evidence from health-education and medical-education reviews suggests that AI tutors and chatbots can enhance short-term knowledge and skills compared to traditional methods, while also increasing learner engagement and perceived efficiency (44, 45).

In medical and health-professions education specifically, recent reviews converge on several near-term gains: adaptive tutoring and feedback at scale; automated question/item generation and formative assessment; rapid literature synthesis for evidence-based learning; multilingual support and accessibility for learners with diverse needs; and low-cost simulation of clinical reasoning via conversational cases—provided human oversight remains central (46, 22). Mentor-like dialogue and multimodal learning paths have been integrated in basic models, which in turn promotes more individualized mastery emphasizing on the importance of fairness and confidentiality guarantees (5, 21).

Policy guidance emphasizes that AI can improve access and reduce costs by automating everyday educational tasks and supporting learners in diverse resource contexts. It is also used transparently and in harmony with pedagogy (47, 48).

Limits of the current evidence. Across reviews, effect estimates are promising but fragile: most studies are small, have short durations, are single-site, and are at moderate to high risk of bias; outcomes often rely on convenience tests rather than performance in authentic clinical tasks. Meta-analytic signals for chatbot-supported learning are positive yet heterogeneous, and durability beyond immediate post-test is rarely measured. Few trials benchmark AI tools against expert human tutoring or measure downstream clinical competence, patient safety, or equity impacts (44, 45).

Discipline-specific syntheses, e.g., nursing, also echo this pattern: AI can personalize learning pathways, streamline grading/feedback, and support clinical judgment training; however, it must be embedded within clear ethical boundaries and curricular objectives, rather than used as a wholesale substitute for instruction (49). Accordingly, near-term priorities include discipline-specific guidelines, validated outcome frameworks, and longitudinal evaluation of competence, equity, and safety before scaling (50, 51, 25, 26).

Risks and emerging threats. Reviews and position statements highlight recurring hazards, including

hallucinations and overconfidence in generated content, the propagation of bias from training data, privacy and confidentiality risks associated with student or patient data, assessment integrity and plagiarism, and dependence that may erode deliberate practice if not carefully scaffolded. Initially, faculty workload may increase due to tool vetting, prompt design, and policy development. Furthermore, poorly governed deployment risks widening, rather than narrowing, digital divides (52, 53, 47). Equally, the reviews are skeptical about large language models that can hallucinate, propagate hidden biases, expose confidential data, and tempt academic dishonesty; overreliance may erode reasoning and documentation skills. Over-automation may also diminish learner agency and motivation; AI should augment, not replace, human struggle, reflection, and professional identity formation (54). Mitigation requires explicit governance (transparency, data protection, bias monitoring), redesigning assessment to value process over product, and structured AI literacy for faculty and students (46, 50).

Table 1. Top 20 countries contributing to publications with the words "AI" and "Education" in the title (PubMed and OpenAlex, 2023–2025)

Country	Frequency-Percentage within the top 20 countries
United States	384 (29.4%)
Canada	146 (11.2%)
China	143 (11.0%)
Australia	83 (6.4%)
India	66 (5.1%)
United Kingdom	57 (4.4%)
Saudi Arabia	48 (3.7%)
United Arab Emirates	43 (3.3%)
Italy	43 (3.3%)
Indonesia	41 (3.1%)
Germany	37 (2.8%)
Iran	*37 (2.8%)*
Spain	33 (2.5%)
Pakistan	29 (2.2%)
Hong Kong	27 (2.1%)
South Korea	23 (1.8%)
Taiwan	22 (1.7%)
Jordan	22 (1.7%)
Sweden	21 (1.6%)

Figure 2. Global distribution of author affiliations for publications with "AI" and "Education" in the title (PubMed and OpenAlex, 2023–2025).-- Most contributions come from high-income countries, particularly the United States; however, a notable share of publications comes from middle- and low-income countries, highlighting the accelerated global diffusion of AI research in education [Graphic, powered by Bing]

Governance and Implementation Guidance

Across reviews, the recommendations are strikingly consistent. AI in education should always keep a **"human-in-the-loop"** approach, with transparency, clear citation of sources, and strong safeguards for data privacy. We must tie tools directly to explicit learning outcomes and evaluate them through rigorous study designs that include equity and safety endpoints (53, 48, 47). Institutions also need to invest in faculty development, redesign assessments to value both process and product, and set explicit norms for when and how
Faculty board members can use AI in coursework and clinical training.
We need to support infrastructure to help make adoption fairer and more scalable—for example, blockchain offers the possibility of verifiable, portable credentials across borders. However, this remains in its early stages (55). A pragmatic roadmap emerging from recent reviews includes five key steps:

(1) Define learner-appropriate use cases—favouring formative over summative applications
(2) Ensure teacher mediation and maintain audit trails
(3) Teach skills in prompt design and verification,
(4) Monitor equity and access to prevent widening divides, and
(5) Rigorously evaluate outcomes before scaling (22, 46).

In future, it seems plausible that technologies such as **"Emotion AI"** and multimodal systems that these advances will require careful validation and strong ethical guardrails before they can be responsibly integrated into medical education (56, 5).

In summary, AI already accelerates parts of the learn-teach cycle—especially feedback, access, and simulation—but its long-run value will depend on rigorous evaluation, ethical governance, and thoughtful curricular integration that strengthens (rather than shortcuts) clinical reasoning and professional identity formation (44, 52). If we keep

educators at the helm and align tools with learning science and ethics, AI can compress the discovery-to-practice cycles and narrow global disparities in medical education—fulfilling the evolutionary arc toward faster, fairer, and more effective learning (33, 4, 5). Table 2 summarizes opportunities, limitations, risks, and governance needs of AI in medical education.

Table 2. Opportunities, Limitations, Risks, and Governance Needs of AI in Medical Education

Category	Key Themes	References
Opportunities	- Personalized/adaptive learning pathways (tailored pace, feedback, multilingual access) - Workflow support (automated material generation, formative assessment, question/item writing) - Simulation/chatbots for clinical reasoning, history-taking, communication - Rapid literature synthesis and evidence translation - Multimodal and mentor-like AI for interactive, immersive learning - Potential to reduce global disparities in access and cost	Shishehgar 2025; Mwuara et al. 2025; Preiksaitis & Rose 2023; Xu et al. 2024; Wang & Jiang 2025; Zapata-Rivera et al. 2024
Limitations	- Evidence base fragile: small, single-site, short-term studies - Outcomes inconsistent, often descriptive rather than evaluative - Lack of longitudinal evidence on competence, safety, and equity - Limited discipline-specific guidelines (dentistry, nursing, pharmacy, midwifery) - Sparse empirical evaluation of AI ethics education	Nagi et al. 2023; Pit et al. 2025; Uribe et al. 2025; Montejo & Andone 2024; Weidener & Fischer 2023
Risks / Threats	- Hallucinations, misinformation, and overconfidence in outputs - Algorithmic bias and inequities - Privacy and confidentiality risks (student/patient data) - Threats to assessment integrity, plagiarism, over-reliance - Risk of reducing learner agency, curiosity, and motivation - Faculty burden for tool vetting, policy creation, and training - Over-reliance on detection tools (false positives/negatives)	Feigerlova et al. 2025; UNESCO 2023; AAMC 2024; Roberts 2024; Otterbacher 2025; Hasan 2025
Governance & Implementation Needs	- Human-in-the-loop oversight, teacher mediation - Transparent disclosure of AI use and citation of sources - Data privacy safeguards and bias monitoring - Faculty capacity-building and AI literacy - Assessment redesign (process as well as product) - Rigorous evaluation with equity and safety endpoints - Explore emerging infrastructure (e.g., blockchain for credentialing; Emotion AI for responsiveness)	

Proposed Action Plan for Harnessing AI in Medical Education

We would like to encourage institutions to approach AI integration with both optimism and vigilance. AI brings opportunities for personalized learning and simulation-based training (44, 22). We have to be careful that any attempt to adopt uncontrolled AI carries risks—including threats to academic integrity, the widening of equity gaps, and the erosion of learner agency (52, 54). We recommend prioritizing capacity building for implementing AI facilitation education by integrating related ethics into the curriculum and strengthen its governance.

AI tools must be aligned with pedagogy, safeguarding data, and rigorously evaluating outcomes. Only in that case, institutions can leverage AI's potential and mitigate its threats. Ultimately, AI should catalyze better education—not a substitute for the human relationships, reasoning, and professionalism that remain at the heart of medical training.

At FMEJ, we prepared an infographic summarizing practical recommendations for board members to integrate AI into medical education responsibly (below). It highlights opportunities for personalization and efficiency, outlines critical safeguards, and emphasizes the importance of faculty leadership in shaping AI adoption (Figure 3). In summary, AI can accelerate, personalize, and scale medical education—but only if educators

1. Adopt AI Where It Adds Value
- Personalize learning (adaptive pace, feedback, multilingual).
- Use chatbots/simulations for clinical reasoning & communication.
- Automate routine tasks (questions, rubrics, summaries).

2. Build Faculty Capacity
- Run AI literacy & prompt-craft workshops.
- Train staff in ethics, privacy, and bias monitoring.
- Engage other educators in co-design of AI use.
- Explore blockchain for credentialing (secure, portable records in the University repository).
- Test Emotion AI for responsive tutoring—only with strong validation.
- Build shared repositories of AI-supported teaching tools.

3. Safeguard Ethics & Integrity
- Teach AI ethics with case-based methods.
- Set clear policies for AI use in coursework.
- Keep humans in the loop; avoid over-reliance on detection tools.

4. Redesign Assessment & Curriculum
- Value process as well as product.
- Align AI use to explicit learning outcomes.
- Pilot discipline-specific guidelines (nursing, dentistry, pharmacy).

Figure 3. Future of Medical Education Journal's summarizing practical recommendations for teaching boards to responsibly integrate AI into medical education

lead, ethics guide, and outcomes are rigorously validated.

Further Reading: Selected Official Guidance on AI in Education

To support responsible and evidence-based adoption of AI in education, several international organizations have published frameworks and recommendations. These documents provide useful guidance on opportunities, governance, ethics, and risks:

- **UNESCO (2021).** *AI and Education: Guidance for Policymakers.* Paris: United Nations Educational, Scientific and Cultural Organization. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000376709
- **UNESCO (2023).** *ChatGPT and Artificial Intelligence in Higher Education:* Quick Start Guide. Paris: United Nations Educational, Scientific and Cultural Organization. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000385838
- **OECD (2023).** OECD Framework for the Classification of AI Systems. Paris: Organisation for Economic Co-operation and Development. Available at: https://oecd.ai
- **European Commission (2021).** *Ethics Guidelines for Trustworthy AI. Brussels:* High-Level Expert Group on AI. Available at: https://digitalstrategy.ec.europa.eu/en/library/ethics-guidelines-trustworthy-ai
- **World Health Organization (2021).** *Ethics and Governance of Artificial Intelligence for Health. Geneva:* WHO. Available at: https://www.who.int/publications/i/item/9789240029200

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