

Generative Artificial Intelligence in Medical Education: Enhancing Critical Thinking or Undermining Cognitive Autonomy?

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Abstract

Generative artificial intelligence (GenAI), based on transformer architectures with self-attention mechanisms, enables the generation of coherent, context-aware text by processing large-scale language datasets. Tools such as ChatGPT, Gemini, and LLaMA are increasingly integrated into medical education, assisting with literature review, clinical reasoning, information synthesis, and scientific writing. While their utility is clear, their impact on critical thinking—a core competency in medical training—remains uncertain. Users report enhanced productivity and linguistic refinement, yet also a risk of cognitive overreliance. Evidence from recent studies is mixed, highlighting both potential gains in learner engagement and risks of passivity or misinformation. Without structured integration and digital literacy training, GenAI may undermine students' autonomy. However, when embedded within thoughtful pedagogical frameworks, these tools may serve as cognitive enhancers. Medical education must adapt to ensure future physicians engage critically and ethically with GenAI in complex clinical environments.

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Original Manuscript

Viewpoint

Generative Artificial Intelligence in Medical Education: Enhancing Critical Thinking or Undermining Cognitive Autonomy?

Abstract

Generative artificial intelligence (GenAI), based on transformer architectures with self-attention mechanisms, enables the generation of coherent, context-aware text by processing large-scale language datasets. Tools such as ChatGPT, Gemini, and LLaMA are increasingly integrated into medical education, assisting with literature review, clinical reasoning, information synthesis, and scientific writing. While their utility is clear, their impact on critical thinking—a core competency in medical training—remains uncertain. Users report enhanced productivity and linguistic refinement, yet also a risk of cognitive overreliance. Evidence from recent studies is mixed, highlighting both potential gains in learner engagement and risks of passivity or misinformation. Without structured integration and digital literacy training, GenAI may undermine students' autonomy. However, when embedded within thoughtful pedagogical frameworks, these tools may serve as cognitive enhancers. Medical education must adapt to ensure future physicians engage critically and ethically with GenAI in complex clinical environments.

Keywords: Generative Artificial Intelligence; Medical Education; Critical Thinking; Cognitive Autonomy; Curriculum Innovation.

Introduction

Critical reasoning is an invaluable tool in medical education, enabling students to develop complex cognitive skills that directly translate into improved decision-making, deeper clinical insight, and safer patient care [1]. This form of thinking goes beyond the mere recall of knowledge, encompassing problem analysis, evidence appraisal, and the generation of well-founded clinical judgments [2]. As such, it is rightly considered a cornerstone of high-quality medical training and professional practice [3].

In recent decades, technological advancements have profoundly reshaped educational ecosystems, including those within medical schools [4]. The advent of the internet and metasearch engines revolutionized access to scientific information, democratizing medical education on a global scale [5]. More recently, we are witnessing another paradigm shift with the emergence of generative artificial intelligence (GenAI) [6]. Tools such as ChatGPT, Claude, DeepSeek, Gemini, Perplexity, LLaMA, and Google Med-PaLM are becoming increasingly embedded in students' academic routines [7]. From clinical reasoning and diagnostic support to the drafting of critical essays and literature reviews, these platforms are rapidly redefining the landscape of medical learning [8]. While their utility is evident, their broader implications particularly regarding the development of critical thinking, a cornerstone of medical training—remain insufficiently explored and continue to generate debate in academic circles.

Implications of Generative Artificial Intelligence in Medical Education

GenAI is a subfield of artificial intelligence that employs advanced machine learning models to generate humanlike language[8]. Large language models (LLMs), such as ChatGPT, Gemini, Claude, LLaMA, and Mistral, are built on transformer architectures that leverage self-attention

mechanisms to evaluate the contextual relevance of words within a sequence[9]. Trained on massive datasets, these models can generate coherent, context-sensitive, and semantically rich responses across a wide range of tasks [10].

Generative AI (GenAI) tools have rapidly permeated educational ecosystems, often outpacing the development of appropriate regulations, curricular integration, and institutional guidelines. In medical education—a field characterized by dense curricula and high performance pressure—these tools offer notable advantages: instant support for complex inquiries, rapid summarization of extensive content, clinical case simulations, and formative feedback [11]. Additionally, GenAI significantly enhances the presentation of assignments, essay quality, and research processes, streamlining academic productivity [12].

While the impact of GenAI on critical thinking remains complex and non-linear, growing evidence reveals its limitations in supporting genuine reasoning tasks. Consequently, a new frontier is emerging Reasoning AI which seeks to embed logical inference, goal-directed problem solving, and human-like cognitive frameworks into AI systems [13]. Unlike GenAI, which focuses on pattern prediction and language fluency, Reasoning AI emphasizes logical thinking, goal-oriented problem-solving, and the ability to synthesize information across multiple steps and contexts. These systems aim to understand not just what to say next, but why — and how each answer fits into a broader sequence of reasoning [14].

Although generative AI shows promising applications in enhancing self-regulated learning and certain dimensions of critical thinking, current evidence remains mixed and context-dependent, with several studies reporting minimal or even negative cognitive impacts when used without pedagogical scaffolding [15–17]. Some studies suggest that GenAI may foster critical reasoning by simulating realistic clinical decision-making environments and supporting self-directed learning [18,19]. For instance, a 12-week randomized trial using a ChatGPT-based tool called *LearnGuide* showed an average increase of more than seven points on the Cornell Critical Thinking Test among medical students [20]. This improvement was sustained two weeks after the intervention ended. The same study also reported enhanced learning “flow” and student engagement factors essential to deep cognitive development.

Another study by Çiçek et al. revealed that ChatGPT-generated feedback in clinical reasoning contexts did not produce statistically significant improvements in critical thinking [21]. In fact, the control group outperformed the AI-assisted group in managing complex clinical cases [21]. These contrasting outcomes suggest that GenAI’s ability to support or hinder critical thinking in medical students may depend on several variables, including tool design, task complexity, and the extent of faculty supervision [15,19].

Beyond performance metrics, broader concerns persist. When used uncritically, GenAI tools may foster cognitive passivity. Habitually outsourcing synthesis or complex analysis to machines can weaken students’ internal reasoning structures. Moreover, the accuracy of AI-generated responses remains inconsistent, and unsupervised reliance can expose students to biased, outdated, incorrect, or even fabricated information [22,23]. Ethical concerns also persist, ranging from plagiarism and data manipulation to the subtle erosion of academic authorship and originality. In these contexts, GenAI ceases to be a mere educational aid and becomes a disruptive force its consequences still emerging and deserving of careful scrutiny [24,25].

Dependence on Generative AI: Risks to Cognitive Autonomy

Critical thinking is not simply a function of information access; it stems from confronting uncertainty, evaluating conflicting hypotheses, and making reasoned decisions often under pressure [26]. In medical training, these are not optional skills but core competencies [27,28]. The concern, then, is not that medical students are using GenAI as part of their learning process, but that they may be delegating essential cognitive tasks to these tools without accompanying them with reflective

processing [3].

This risk is especially acute in environments where students are not trained to critically engage with AI-generated outputs [23]. When AI becomes a substitute for expertise rather than a complement, students may forgo the processes that foster critical reasoning skills foundational to safe clinical practice [29]. If today's and tomorrow's medical students are not equipped to question information—regardless of its source—the integrity of their clinical judgment will be compromised [30,31].

AI design limitations also deserve attention. While some tools have shown promise in guided reasoning tasks, others lack the sensitivity or contextual awareness to manage complex, atypical, or ethically nuanced cases [14,32]. Overreliance on these tools can lead to overestimating their accuracy and reliability, especially when design features are opaque or lack safety mechanisms to alert users medical students in this case—to potential or common errors [33].

The Future of Generative AI in the Medical Curriculum

Although the evidence remains mixed regarding its influence on higher-order cognitive skills such as critical thinking, the integration of technology into modern curricula appears both inevitable and essential to prepare students for the demands of 21st-century education [34]. Faculty members must go beyond basic familiarity and proactively embed GenAI into their teaching strategies. This involves promoting active engagement with the tools [29], encouraging students to question outputs, identify biases, validate sources, and reflect critically on AI-generated information, such integration must not diminish, but rather strengthen, cognitive autonomy [35]. This multidimensional relationship is summarized in Figure 1, which outlines the key variables that mediate whether GenAI enhances or undermines cognitive autonomy in medical education (Figure 1).

Figure 1. Conceptual model of the implications of GenAI in medical education. The diagram presents a balanced framework outlining the potential cognitive benefits and associated risks of GenAI tools.

Universities bear the institutional responsibility of evaluating the quality, accuracy, and ethical implications of GenAI tools before their widespread adoption. As personalized tutors or virtual classroom assistants, GenAI systems can support adaptive learning paths and formative assessment. However, this requires clear transparency in model design, strong data governance protocols, and continuous oversight by academic staff to avoid misinformation or algorithmic bias [36].

Crucially, the future of GenAI in medical education must also embrace the expanding potential of immersive technologies. Virtual learning environments, augmented reality (AR), and extended reality (XR) platforms, when combined with GenAI, can simulate clinical encounters, anatomy labs, or public health scenarios—offering experiential, safe, and scalable training modalities (REF). These immersive spaces enhance engagement, reduce learning gaps, and prepare students for complex decision-making under uncertainty.

To ensure ethical and effective use, digital literacy should become a foundational component of medical training[37]. This includes prompt engineering, AI output interpretation, critical appraisal of algorithmic content, and bias recognition. Without these competencies, students risk becoming passive consumers of AI output rather than critical users capable of navigating complex health information landscapes.

Ultimately, critical thinking will not emerge from an algorithmic echo chamber, but through deliberate practice, intellectual curiosity, and a curriculum designed to blend human judgment with machine efficiency. The opportunity lies not in resisting AI integration, but in designing an educational paradigm where GenAI enhances not replaces clinical reasoning and ethical decision-making.

Conclusions

The emergence of generative artificial intelligence in medical education represents a profound inflection point, full of potential and risk. These tools can enrich medical education by supporting overwhelmed students and faculty, personalizing learning, and catalyzing the development of cognitive skills. But they are not neutral. Used without critical intent, they may undermine the very qualities—judgment, skepticism, ethical clarity—that define effective medical professionals.

The future of medical education lies not in rejection or blind adoption, but in thoughtful integration. GenAI should be viewed neither as a threat nor as a salvation, but as a catalyst reflecting the strengths and weaknesses of our pedagogical systems. The task ahead is clear: to train a generation of physicians who are not only technologically competent but critically empowered. This—more than any algorithm—will shape the quality of care we provide in the decades to come.

Conflicts of Interest

None declared.

Abbreviations

AI: Artificial Intelligence

AR: Augmented Reality

GenAI: Generative Artificial Intelligence

LLM: Large Language Model

XR: Extended Reality

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Supplementary Files

Figures

Conceptual model of the implications of GenAI in medical education. The diagram presents a balanced framework outlining the potential cognitive benefits and associated risks of GenAI tools.

