Babylonian Journal of Machine Learning
Vol.2025, **pp**. 97–105
DOI: https://doi.org/10.58496/BJML/2025/008; ISSN: 3006–5429
https://mesopotamian.press/journals/index.php/BJML

Research Article

The Impact of Generative AI on Advancing Graduate Medical Education

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ARTICLEINFO

Article History

Received 07 Apr 2025
Revised 13 May 2025
Accepted 15 Jun 2025
Published 10 Jul 2025

Keywords

Generative AI (GAI)

Graduate Medical Education (GME)

Personalized Learning

Clinical Decision Support

AI-powered Simulations

ABSTRACT

Graduate Medical Education (GME) is integral to the development of healthcare professionals, but traditional educational methods are often limited in resources, limited in time, and do not meet the needs of students from all backgrounds. As generative artificial intelligence (GAI) advances, it is possible to enhance and personalize GME to address some of these challenges. With GAI, you can create content, create personalized learning pathways, train using simulations, and get feedback in real-time, such as ChatGPT, one of the large language models. Medical training can be revolutionized by these technologies, which allow educators to create dynamic, tailored learning experiences and provide students with realistic, interactive clinical scenarios. While GAI has great potential, its integration in medical education raises ethical concerns, privacy concerns, bias concerns, and mentorship concerns. Having generative AI integrated into GME can have significant effects on the quality of curriculum delivery, clinical decision-making skills, and patient outcomes. This paper explores the benefits, challenges, and future prospects of this integration.

1. INTRODUCTION

As a physician's training progresses, his or her graduate medical education (GME) becomes more and more important, influencing their clinical skills, knowledge base, and professional identity. Mentorship and clinical rotations are often the primary means of imparting essential competencies in traditional GME models. It is important to note that these methods can be resource-intensive, time-consuming, and may not always meet the diverse learning needs of each trainee[1]. Artificial intelligence (AI), and particularly generative artificial intelligence (GAI), offer new opportunities for enhancing and personalizing GME, potentially overcoming some of its limitations. An AI model that generates new content, such as text, images, and audio, by learning patterns from existing data can be referred to as GAI [2]. There has been considerable success with these models in various fields, including healthcare, including large language models (LLMs) like ChatGPT [3]. Medical educators are able to transform medical education with their ability to generate human-like text, summarize complex information, and create interactive learning experiences. In recent years, generative artificial intelligence (AI) technologies like ChatGPT and Bard have gained prominent attention for their potential applications as well as implications for medical education [4], [5]. A wide variety of applications are being investigated for these systems originally intended for testing and honing AI technology [6]. Several fields are finding applications for generative AI, which creates content such as text, images, audio, computer code, and video, using machine learning techniques [5], [6]. The challenge remains in harnessing this technology in a way that is ethical, responsible, and equitable [7],[8],[9]. As a result of this intersection, intense discussions and conjectures have emerged about AI's role in medical education and its potential uses. A thoughtful, informed approach is required when integrating. In addition to understanding AI's capabilities and limitations, medical educators must develop a plan for the future. Using generative AI as a means of improving medical education. It has been demonstrated that large language models (LLMs) have a broad range of applications in medicine Figure 1, including administrative tasks and clinical applications.

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A rapid advancement in Artificial Intelligence (AI) in medical education has led to innovative methods of improving learning and teaching [10]. The generative AI technology stands out as one of the most promising AI technologies, with its capacity to provide personalized learning, content creation, simulation, and decision-making capabilities. It focuses on how AI-driven tools can revolutionize medical training and clinical practice, as well as how they can advance Graduate Medical Education (GME). Educational experiences are enhanced with generative AI because it facilitates the creation of realistic scenarios, facilitates personalized feedback, and makes learning resources easier to access. In this paper, we examine how these technologies can be used to improve educational outcomes, clinical decision-making skills, medical research, and student engagement[11]. A major focus of our work is also on the ethical use of AI, data privacy concerns, as well as the need to adapt the educational system in order to keep up with these technological advancements. Overall, this study illustrates how generative AI can shape the future of medical education, enhancing its efficiency and effectiveness.

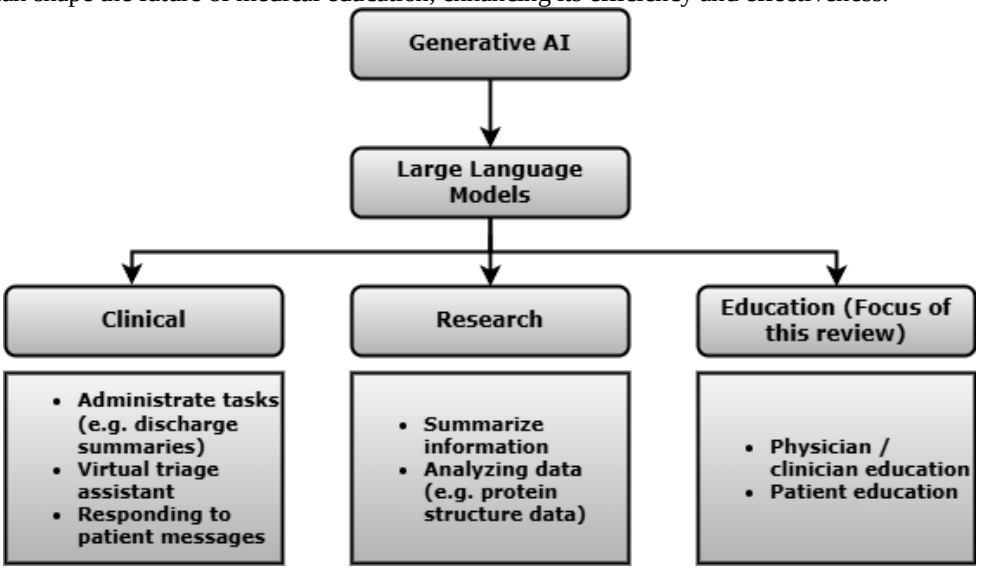

Fig. 1. Applications of Generative AI in Medicine.

With AI's rapid advancement, especially in the form of generative AI, education across multiple disciplines, including medicine, is being transformed[12]. Graduate medical education (GME) uses generative artificial intelligence (AI) technologies such as large language models, automated content creation tools, and intelligent tutoring systems to deliver, absorb, and apply medical knowledge. As a result of these innovations, clinical training can be enhanced, learning experiences can be personalized, and critical thinking and decision-making skills can be developed among medical students. Health care has many challenges to overcome, such as implementation of diagnostics, facilitation of diagnoses, and decision-making using artificial intelligence (AI) [13], [14]. A large language model (LLM) is an example of generative AI (GAI), which can be applied to all areas of social life [15]. By analyzing the context of words that come before a given sequence of words, LLMs are able to predict its probability differently from previous deep learning algorithms [16]. When sufficient textual data is learned, LLMs are capable of producing natural and meaningful language sequences.

Due to GAI algorithms' widespread application, the potentials and risks are being debated [17]. Meanwhile, studies have raised concerns about ChatGPT's ethical considerations, evaluation practices, scientific integrity, as well as potential negative effects on students' higher order thinking skills [18]. Despite the fact that GAI algorithms may contain factual errors and biases, they consistently improve student learning through nuanced responses. As a result, many researchers anticipate that higher education will offer new methods for teaching and assessment that will cope with the realities of living, working, and learning in an age of free access to AI [19]. In particular, generative artificial intelligence (AI) is an example of a transformative technology. An algorithm that generating new content from existing data is generative AI, as its name implies. Using this tool set, students can engage more effectively in their education at GME institutions and be imparted medical knowledge. By integrating generative AI into GME, new opportunities for personalized learning, improved patient simulations, enhanced clinical decision-making, and more efficient administrative procedures can be explored.

2. RELATED WORK

In this technology, advanced machine learning models are used to generate expressions that resemble human expressions. As part of their self-attention mechanism, transformers can determine the relative importance of words in a sequence. This

improves the model's ability to comprehend context and results in remarkable abilities to understand and generate text that is human-like when trained on vast amounts of data [20]. As conversational chatbots, these models excel at summarizing documents, analyzing sentiment, answering questions, analyzing texts, translating texts, and generating texts. Images, audio, and video can be processed and generated using models which are related. As GenAI becomes more widely integrated into our everyday lives, it is expected to have a far-reaching societal impact [21]. There is a strong possibility that GenAI will revolutionize multiple industries, including healthcare and education. A variety of healthcare applications are being explored with GenAI, Research support and clinical decision support, as well as medical education and clinical documentation. Despite their lack of medical knowledge, ChatGPT, for example, performs well on all three USMLE Step 2 examinations with GenAI models, even without fine-tuning [22]. There are mixed results in studies evaluating LLM performance on board examinations and in-service examinations, but in some cases it is comparable to that of senior medical students. It has been shown that GenAI-powered tools are able to improve provider burnout and EHR-related inefficiencies [23].

Academic physicians, who make up most GME faculty, also suffer from burnout, which may affect the quality of their training. As a result, innovations that avoid overwork and burnout may benefit trainees and faculty in GME programs. There have been several attempts at reducing physician documentation burden, such as using medical scribes, implementing educational interventions, and improving workflows. In addition to generating and summarizing text, GenAI has the capability to summarize, translate, and summarize. Among the most notable applications of GenAI today are ambient listening tools that transcribing and analyzing physician-patient conversations to create [24]. Compared to 60 years ago, when students were first taught basic life support with mannequins, simulation-based medical education has evolved significantly, and virtual and augmented reality are now integral components to graduate medical education. Several studies have demonstrated the effectiveness and transferability of simulation-based training to actual patient care [25]. As part of GME programs, simulations are used to educate students as well as assess their performance. On residents in anesthesiology as part of the board examination process, as a way of assessing communication, professionalism, and technical abilities [26]. SBME is used extensively in GME to teach procedural skills like complex surgical techniques, providing trainees with experience with procedures that are invasive, uncommon, or high-acuity [27]. With artificial intelligence integrated into clinical simulations, trainees' skill levels and performance data could be custom-adapted, creating a more personalized learning environment and potentially allowing for new patient simulations.

It is more effective to receive individual tutoring than to learn in a traditional classroom setting in order to achieve better academic results. Teaching professionals can provide tailored and accessible explanations for complex topics to learners at varying levels. Tutoring delivered by humans can be expensive, and there aren't enough qualified teachers everywhere, but GenAI tools may offer some of the same advantages. It is possible to use LLMs to tutor graduate medical trainees, and they could serve as tools to explain challenging concepts [28]. Study results showed that radiology reports generated by trainees were reviewed successfully and educational feedback was provided in Table 1.

TABLE I. EXISTING RESEARCH OF THE HEALTHCARE PROPOSED BASED ON THE GENAI.

Specialty	Reference	Description
Administration	An exploration of artificial intelligence's potential in the field of graduate medical education [29]	An analysis of GenAI's use in GME applications.
Administration	What is ChatGPT's compatibility with your program? [30]	An analysis of GenAI's use in GME applications.
Anesthesiology	Simulation of simulated patient encounters using generative conversational artificial intelligence: a pilot study in anaesthesia training [31]	In this study, trainees will be given the opportunity to simulate patient conversations using an LLM. A good deal of accuracy was demonstrated in simulating the responses and behaviors of patients.
Emergency Medicine	A perspective from emergency physicians on using generative AI to generate clinical summaries [32]	In this study, trainees will be given the opportunity to simulate patient conversations using an LLM. A good deal of accuracy was demonstrated in simulating the responses and behaviors of patients.
Emergency Medicine	A Proof of Concept: Discussing bad news with emergency physicians with ChatGPT [33]	An experiment to prove ChatGPT's feasibility in handling bad news.
Neurosurgery	An Innovative and Opportunities-Focused Approach to ChatGPT and Neurosurgical Education [34]	Analyzes the literature and summarizes how GenAI is used to educate neurosurgery trainees.
Neurosurgery	Taking the written examination of a neurosurgery resident with ChatGPT: Probing artificial intelligence in neurosurgical training [35]	An LLM cannot produce board examination-style questions on evaluation of its performance was based on a sample set of high-quality questions.
Neurosurgery	Using transformer architectures to develop educational videos for neurosurgery [36]	The purpose of this document is to describe a planned study which involves creating synthetic neurosurgical training videos based on a diffusion model.
Ophthalmology	The use of large language models in the education of ophthalmologists: Customized instructions and enhanced retrieval abilities [37]	An introduction to teaching clinical guidelines in ophthalmology, using LLMs, and a summary of the current research in the field.

Orthopedic Surgery	Comparing AI-derived content for graduate medical education in total joint replacement with orthopaedic fellows [38]	An LLM was used to generate educational summaries related to total joint arthroplasty, and its content was found to be superior to that created by orthopedic fellows on several topics.
Pathology	A Practical Approach to Generative AI in Pathology [39]	The use of GenAI to educate pathology trainees has been reviewed and summarized in the literature.
Pediatrics	A comparison of ChatGPT-assist versus traditional teaching methods for improving clinical skills in pediatric trainees [40]	The results of a study on pediatric clinical skill education found that LLM-assisted instruction was comparable to or superior to traditional instruction.

3. GENERATIVE AI AND ITS APPLICATIONS IN EDUCATION

AI that generates new content, involving more than just data analysis and predictions, is called Generative AI (GAI) [41]. In contrast to traditional AI systems that use existing data to recognize patterns, GAI models can produce content that appears to be created by humans in many ways. As a result of their underlying architecture, they are capable of learning statistical relationships and patterns in data based on extensive training datasets. It is remarked that large language models (LLMs) are one of the most prominent types of GAIs, as they are able to process and produce human language [42]. Generative Pre-trained Transformers (GPTs) learn from massive text corpora, enabling them to understand and produce coherent, context-relevant text [43]. In addition to summarizing text, answering questions, creating content, and translating languages, a LLM can also be used for creating translations from one language to another.

a Applications of GAI in Education

As a result of GAI's versatility, it has been used in a wide range of educational settings, including primary schools as well as higher education institutions. GAI tools can be used to enhance the learning process in general education, provide writing assistance, and automate administrative tasks. For instance, GAI can also assist in curriculum design, generating lesson plans and assessment materials. In higher education, GAI is being explored for its potential to enhance research, facilitate collaboration, and improve student engagement. Students can use GAI tools for brainstorming, literature review, and data analysis. Educators can leverage GAI to create interactive learning modules, automate grading, and provide personalized feedback to students. However, the integration of GAI in education also raises concerns about academic integrity, bias, and the need for critical evaluation skills [44].

b GAI in Medical Education: A Nascent Field

While the application of GAI in general education is gaining traction, its use in medical education, particularly GME, is still in its early stages. However, the potential benefits are significant. Medical education requires the acquisition of a vast amount of knowledge, the development of complex clinical reasoning skills, and the cultivation of empathy and professionalism. GAI can potentially assist in all these areas, providing personalized learning experiences, simulating clinical scenarios, and offering feedback on trainee performance [45]. The following sections will delve into the specific applications of GAI in GME, exploring its potential to transform various aspects of physician training. We will also address the challenges and ethical considerations associated with its implementation, ensuring a balanced and informed perspective on the role of GAI in shaping the future of medical education.

4. THE ROLE OF GENERATIVE AI IN GRADUATE MEDICAL EDUCATION

Generative AI has several applications in GME, ranging from content creation to real-time feedback and clinical simulations. Below are some of the key areas where generative AI is making an impact:

a Personalized Learning Pathways

Generative AI can tailor medical education to the specific needs of individual learners. By analyzing learner performance and identifying gaps in knowledge, AI-driven platforms can generate personalized learning plans. These systems can adapt the content based on the learner's progress, helping students focus on areas where they need the most improvement, while accelerating their exposure to topics they have mastered. This customization enhances learning outcomes and can foster more efficient mastery of complex medical knowledge.

b Simulation-Based Learning

Clinical simulations are an essential component of medical education, allowing students to practice skills in a risk-free environment. Generative AI can enhance simulation-based learning by creating dynamic, realistic clinical scenarios. These AI-driven simulations can generate unique patient cases, varying conditions, and evolving clinical situations in real time. Decision-making, and procedural skills without the ethical and logistical concerns of real-world patient interactions.

c Clinical Decision Support and Virtual Mentorship

Generative AI can serve as a virtual mentor, providing students with personalized feedback and clinical decision support. For example, AI models can analyze a student's diagnostic decisions and recommend improvements based on clinical guidelines and evidence-based practices. This immediate feedback loop can accelerate learning, helping students refine their clinical judgment and apply theoretical knowledge to real-world situations. Additionally, AI-powered systems can generate case studies and clinical scenarios, helping students build a more comprehensive understanding of patient care.

d Content Generation and Curriculum Design

AI can assist educators in creating tailored content, ranging from quizzes and exams to lectures and interactive modules. Generative AI can synthesize existing medical literature, case reports, and research papers to create up-to-date, accurate educational materials. This capability can ease the burden on educators by automating content creation and ensuring that students receive the most relevant, evidence-based information. Furthermore, generative AI can optimize curriculum design by identifying the most effective teaching methods and content delivery formats based on student performance and engagement data.

e Research and Knowledge Discovery

AI can also accelerate medical research by assisting medical professionals and students in analyzing large datasets, identifying patterns, and generating hypotheses. Generative AI systems can automate the process of synthesizing existing research and generating novel research proposals. This can lead to more efficient scientific discovery and contribute to the development of new medical treatments, diagnostic tools, and care protocols. In GME, such tools can enable students to engage in research projects that contribute to the evolving body of medical knowledge.

5. BENEFITS OF GENERATIVE AI IN GME

The integration of generative AI into GME offers several compelling benefits, including:

a Enhanced Learning Efficiency

AI-driven personalized learning pathways allow students to focus on their individual learning needs, reducing wasted time and improving the efficiency of the educational process. By analyzing performance data, AI can ensure that students receive the most relevant content at the right time, maximizing learning outcomes.

b Scalability and Accessibility

By offering AI-driven content and simulations, educational institutions can provide high-quality education to students regardless of location, reducing barriers to entry for medical training and improving access to healthcare education worldwide.

c Improved Patient Safety and Quality of Care

By enhancing clinical decision-making and providing students with realistic simulations of patient interactions, generative AI can improve medical education outcomes, which in turn can enhance patient care. Well-trained professionals, equipped with better decision-making tools and realistic clinical experiences, are more likely to provide accurate diagnoses and treatment plans, ultimately improving patient safety.

d Reduced Costs and Increased Efficiency

Generative AI can reduce the costs of medical education by automating administrative tasks, content creation, and student assessments. These cost savings can be reinvested into other areas of medical training, such as improved technology infrastructure, research initiatives, and the recruitment of top educators. The efficiency gains from AI-based systems also enable educators to devote more time to direct student interaction and mentorship.

6. CHALLENGES AND ETHICAL CONSIDERATIONS

While generative AI offers numerous benefits, its application in GME presents several challenges and ethical concerns:

a Data Privacy and Security

AI systems rely on large datasets of student and patient information, raising concerns about data privacy and security. Educational institutions must ensure that they adhere to strict data protection regulations, such as HIPAA in the U.S., to prevent misuse of sensitive information.

b Bias and Fairness

A machine learning system is only as good as the data it is trained on. Using biased or incomplete datasets may result in incorrect outcomes, particularly for groups underrepresented. This could perpetuate disparities in medical education and care. Addressing bias in AI models and ensuring fairness is critical to the success of generative AI in GME.

c Teacher-Student Relationship

The use of Artificial Intelligence (AI) can enhance learning, but it cannot replace the emotional support, mentorship, and real-time interaction that is an integral part of education. The relationship between educators and students is vital in medical training, and AI should be viewed as a tool that complements, rather than replaces, this human connection.

d Integration into Existing Curriculum

Integrating AI tools into established medical curricula can be challenging, particularly in institutions with traditional teaching methods. Educational systems need to be adaptable and open to innovation in order to effectively implement AI technologies into existing programs.

7. FUTURE DIRECTIONS

As generative AI technologies continue to evolve, their role in GME will likely expand. Future developments may include:

- **Enhanced Personalization:** AI systems could become even more adept at personalizing the learning experience, adapting to students' evolving needs in real time.
- **Advanced Clinical Simulations:** The development of more sophisticated AI-driven simulations could create lifelike patient interactions that further improve clinical training.
- **AI-Powered Research Assistance:** AI could assist students in conducting research more efficiently, from literature reviews to hypothesis generation and data analysis.
- **Global Collaborations:** AI may facilitate global collaborations in medical education, allowing students and educators to interact across borders and share knowledge in real time.

8. CONCLUSION

Generative AI has the potential to significantly transform Graduate Medical Education by offering new ways to personalize learning, enhance clinical decision-making, and improve access to training resources. AI-driven tools can tailor educational content to the specific needs of individual students, creating more efficient and effective learning pathways. Furthermore, AI-powered simulations and clinical decision support systems offer students realistic, risk-free environments to practice and refine their skills. However, challenges related to data privacy, fairness, and the preservation of the teacher-student relationship must be addressed to ensure the responsible integration of AI in GME. As AI technologies continue to evolve, their role in medical education will likely expand, offering further opportunities for global collaboration, personalized learning, and advanced clinical simulations. The future of GME lies in harnessing the power of AI while maintaining the essential human elements of education and patient care.

Conflicts of Interest

The author's paper emphasizes that there are no conflicts of interest, either perceived or actual, that could impact the research integrity.

Acknowledgment

The author expresses gratitude to the institution for their provision of software tools and equipment that supported data analysis and visualization.

Funding

This research received no external funding

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