

# Medical Education in the Era of Artificial Intelligence

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## ABSTRACT

The "Four New" initiatives have emerged as a pivotal framework for advancing higher education in China. Among these, the promotion of New Medical Sciences not only meets the evolving demands of the contemporary era but also defines the future trajectory of medical education. Artificial Intelligence (AI) has become a hallmark of this epoch, serving as a transformative force that reshapes medical education paradigms. Since the global shift to large-scale online education prompted by the COVID-19 pandemic, the exploration of AI applications in higher education has progressed substantially. Given the inherently practical and highly specialized nature of medical education, the integration of AI technologies has become imperative to address its multifaceted challenges. This paper elucidates the unique complexities and critical challenges in medical education, examines the potential application scenarios of AI within this domain, and highlights key considerations for its effective implementation.

**Keywords:** Artificial intelligence, Medical education, New Medical Sciences, Talent cultivation, Teaching reform.

## INTRODUCTION

In August 2018, following the National Education Conference, the Central Committee of the Communist Party of China officially outlined the strategic focus of higher education on the development of New Engineering, New Medical Sciences, New Agriculture, and New Liberal Arts, thereby introducing the concept of "New Medical Sciences" for the first time. Wu Yan, Vice Minister of Education, underscored that New Medical Sciences embody novel paradigms, emerging contexts, and innovative disciplines. Scholars have further expanded on this framework, delineating it across five dimensions: new paradigms, new structures, new models, new quality standards, and new systems. The establishment of New Medical Sciences represents not only a necessary response to the external imperatives of the era but also an intrinsic demand for the advancement of medical education. The emergence of groundbreaking technologies such as blockchain, the metaverse, and ChatGPT has rendered the contemporary world increasingly complex and multifaceted. In

particular, ChatGPT, as a representative of the next-generation general-purpose Artificial Intelligence (AI), is poised to disrupt application scenarios across various domains, including medical education (Sallam, 2023; Department and Ireland, 2023; Mehta *et al.*, 2024; Inoue *et al.*, 2024; Kalidindi, and Janani Baradwaj, 2024). Unlike the networked technologies that previously revolutionized human production and lifestyles as sophisticated tools under human control, this new wave of AI appears capable of transcending such constraints. It autonomously generates immersive virtual environments that blur the boundaries between reality and illusion, potentially entrapping individuals in indistinguishable virtual existences. While the rapid evolution of AI has significantly enhanced productivity, it has also introduced substantial risks and ethical dilemmas, particularly in areas such as its practical applications, governance, and broader implications for human identity and societal norms (Morley *et al.*, 2019; Mittelstadt, 2019; Sousa *et al.*, 2019; Jobin *et al.*, 2019; Azencott, 2018; Floridi *et al.*, 2018; Ananny and Crawford, 2018; Akgun and Greenhow, 2021). This paper seeks to critically analyze the pressing challenges confronting medical education, explore the potential applications of AI to address these challenges, and anticipate emergent ethical and practical issues. Ultimately, it aspires to provide actionable insights for educators striving to innovate and transform medical education.

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## CHALLENGES IN MEDICAL EDUCATION

### Addressing Complex Medical Issues through Multidisciplinary Approaches

Medical education is inherently interdisciplinary, encompassing an extensive range of fields, including chemistry for pharmacological studies, physics for medical instrumentation, psychology and sociology for patient interaction, and the foundational biological sciences underpinning medical practice. Reflecting this complexity, many countries have implemented a four-phase medical education framework, comprising premedical, basic medical, clinical medical, and residency training stages (DeZee *et al.*, 2012). Typically, students complete four years of premedical and basic medical education before progressing to clinical training and residency. China has emerged as a global leader in promoting the "Four New" initiatives in higher education, including the development of New Medical Sciences. At the core of cultivating talent in New Medical Sciences is the ability to harness multidisciplinary knowledge and skills to address complex medical challenges. Artificial Intelligence (AI) has proven to be a transformative enabler of such interdisciplinary approaches in medical education. For instance, the UK Research and Innovation (UKRI) initiative at the University of Edinburgh has established "AI+" doctoral training centers, focusing on healthcare and biomedicine. This innovative strategy to foster research and enhance innovation capabilities exemplifies an effective model for training medical professionals (Rudin and Gould, 2023).

### THE EXPONENTIAL GROWTH OF SPECIALIZED MEDICAL KNOWLEDGE

Medicine is one of the most specialized academic disciplines, demanding mastery of an expansive body of knowledge. This encompasses foundational medical sciences such as anatomy, physiology, pathology, and pharmacology, alongside clinical disciplines including internal medicine, obstetrics and gynecology, surgery, and pediatrics. Furthermore, students are often required to undertake a wide range of general education courses. Many medical students express frustration at the overwhelming breadth and depth of medical knowledge, citing not the absence of resources but the challenge of determining where to begin amidst the vast information available. AI-based learning platforms, search engines, and educational software have emerged as powerful tools to assist students in organizing, synthesizing, and systematizing knowledge. By leveraging these technologies, medical students can effectively navigate the extensive landscape of medical information, enabling them to streamline their learning processes and construct comprehensive knowledge frameworks.

### The Crucial Role of Clinical Practice

Medicine, as a practice-oriented discipline, places significant emphasis on clinical training, which is an indispensable component of medical education. Through repeated hands-on practice, students develop essential skills for identifying patient symptoms, diagnosing conditions, and formulating treatment strategies. Moreover, clinical training fosters teamwork, communication, and interpersonal skills, which are vital for effective medical practice. However, the expansion of higher education enrollment in China, coupled with increased patient awareness, decreased patient compliance, and strained doctor-patient relationships, has resulted in fewer opportunities for medical students to gain sufficient clinical experience. AI-driven virtual simulation technologies offer an innovative solution to this challenge, enabling students to engage in immersive, practice-oriented learning within controlled virtual environments.

### Rapid Evolution of Medical Knowledge Systems

Technological advancements have driven medical science into an era of unparalleled growth. Over time, the field of medicine has evolved through three distinct systems: traditional Chinese medicine, representing the first generation; modern Western medicine, constituting the second generation; and, most recently, quantum medicine, which defines the third generation. Quantum medicine employs advanced instrumentation to perform qualitative, semi-quantitative, and quantitative analyses of disease frequencies and spectra, as well as the frequency properties of pharmaceuticals (Capozziello *et al.*, 1999; Bose and Chakraborty, 2020). To align with this rapid progression in medical science, medical education must continually evolve. The dynamic nature of medical knowledge and skills demands that students develop the ability to learn, adapt, and innovate independently. Today, more than ever, medical students are required to cultivate competencies such as autonomous learning, critical thinking, and analytical reasoning. However, the prevalence of examination-focused education systems has hindered the development of these essential skills, leaving many students ill-prepared for the complex demands of future medical environments. AI, empowered by big data analytics, has the potential to bridge this gap by providing students with personalized learning plans. These plans are tailored to enhance students' independent learning capacities, enabling them to meet the evolving demands of modern healthcare.

Therefore, medical education necessitates that students possess a comprehensive knowledge base, practical skills, high standards of professional and ethical competence, and the ability to continuously update their knowledge. As shown in Figure 1, to address the challenges currently faced in medical education, it is imperative to integrate modern teaching tools such as AI. By doing so, we can enhance the effectiveness of training programs

and better prepare students to navigate the complexities of an ever-evolving medical landscape.

## APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN MEDICAL EDUCATION

### Virtual Patient Cases

Virtual patient cases employ advanced computer technologies and Virtual Reality (VR) to develop educational tools that closely mimic real-world clinical scenarios. These systems are designed to simulate a diverse range of medical conditions, encompassing symptoms, clinical signs, diagnostic pathways, and therapeutic interventions, all within a controlled clinical practice environment. Typically developed through collaboration among medical experts, software developers, and graphic designers, these tools ensure a high degree of accuracy and realism. Virtual patient cases are accessible through computers or mobile devices, enabling students to engage in interactive, immersive learning. In the context of medical education, these cases serve as an invaluable pedagogical resource, allowing students to perform risk-free simulated clinical practices, thereby honing their clinical skills. For instance, domestic research teams have pioneered the development of the AIteach system, which integrates real case studies with natural language processing to construct virtual patient cases, demonstrating remarkable efficacy in cultivating clinical reasoning skills (Wang *et al.*, 2022).

### Realistic Simulation of Traumatic Surgeries

Virtual surgical simulation systems are capable of recreating highly realistic surgical scenarios, capturing intricate and challenging details of operative procedures. These systems bridge the gap created by limited access to real-world surgical practice for medical students and also function as preoperative training platforms and intraoperative support tools. Examples include simulations for procedures such as fracture reduction and surgical suturing (Sheriff *et al.*, 2024; Mu *et al.*, 2024; van Rijn *et al.*, 2024; Suárez *et al.*, 2024). Through virtual simulation technologies, these systems replicate authentic surgical environments on computer platforms, enabling students to execute simulated procedures via interactive interfaces. This interactive approach allows students to become proficient in the handling of surgical instruments, master safe and precise operative techniques, and gain a comprehensive understanding of surgical protocols and critical steps. Additionally, virtual surgical systems provide students with opportunities to make and rectify mistakes, offering instant feedback and guidance to prevent recurrence of errors, thereby fostering a safe and effective learning environment.

### Promoting Autonomous Learning

Virtual patient cases empower students to learn at their own pace and on their own schedule, facilitating enhanced comprehension and retention of knowledge. The ability to practice repeatedly

allows learners to reinforce their understanding and improve their memorization of medical concepts, ultimately resulting in a deeper grasp of the subject matter.

### Enhancing Interactivity and Engagement in Learning

The sophisticated design, lifelike visualizations, and interactive components of virtual patient cases foster greater student engagement and enjoyment in the learning process. By offering a more dynamic and captivating educational experience, these tools significantly improve both learning outcomes and overall satisfaction among students.

### Boosting Confidence and Clinical Experience

Medical students often experience anxiety and hesitation when initially interacting with real patients. Virtual patient cases provide a safe and controlled environment for students to practice patient management, helping them build confidence in their ability to handle real-life clinical scenarios. Furthermore, these tools enable students to accumulate valuable clinical experience, which is critical for their professional development.

### Tracking Student Learning Progress

Virtual patient cases are equipped with features to record each student's learning journey, including their performance and engagement. These data-driven insights allow medical educators to conduct precise assessments of students' progress and tailor their instructional approaches accordingly, thereby enhancing the overall effectiveness of teaching strategies.

### Transition from Adaptive Learning to Intelligent Adaptive Learning

Adaptive learning refers to a pedagogical approach that dynamically personalizes learning content and methodologies by automatically analyzing learners' behaviors, capabilities, and needs. Leveraging advanced computer technologies and Artificial Intelligence (AI) algorithms, this approach identifies the strengths and weaknesses of individual learners, subsequently tailoring the difficulty, pace, content, and format of instruction to enhance both learning effectiveness and efficiency.

This methodology empowers learners to actively engage with personalized educational processes, enabling them to maximize their potential and optimize learning outcomes. Compared to conventional instructional methods, adaptive learning demonstrates superior efficiency, a more enriched learning experience, and improved results. As digital learning environments continue to evolve at an accelerated pace, adaptive learning has emerged as a dominant paradigm and a crucial direction for the future of education.

The application of adaptive learning in medical education is particularly expansive. Given the rigorous and complex nature of medical training, adaptive learning serves as a transformative

tool that facilitates mastery of intricate medical knowledge while significantly enhancing both efficiency and efficacy. On one hand, it supports medical students in deepening their comprehension and practical application of medical concepts and equips them with the skills to solve complex clinical problems. For instance, during the study of disease diagnostics and treatment protocols, adaptive learning adjusts the content and level of difficulty based on a student's progress and understanding, ensuring thorough and effective knowledge acquisition. On the other hand, adaptive learning proves invaluable for exam preparation and performance evaluation. By analyzing a student's knowledge level and aligning it with examination requirements, adaptive learning systems can recommend appropriate study materials and exercises, thus improving both preparedness and outcomes.

The rapid advancement of foundational AI technologies, such as knowledge graph systems and generative AI, coupled with the development of large-scale model databases, has accelerated the evolution of adaptive learning into what is now termed intelligent adaptive learning (Paranjape *et al.*, 2019; Ullah *et al.*, 2021; Zhang *et al.*, 2022; Shimizu *et al.*, 2023; Lyu *et al.*, 2024; Leng, 2024). Building on the foundational principles of adaptive learning, intelligent adaptive learning employs large-scale data training powered by AI to develop a deeper understanding of and connections between the intricate relationships within medical knowledge. This enables the delivery of more precise and personalized learning platforms for medical students.

Notably, some research institutions have incorporated role-playing technologies within intelligent adaptive learning systems, allowing students to engage in simulated dialogues with AI. These systems analyze students' progress, evaluate learning difficulties, anticipate potential challenges, and provide timely, precise interventions to optimize outcomes. Such innovative models are particularly beneficial for medical students. By engaging in realistic simulated environments, where they

communicate with virtual patients and their families, students not only reinforce their clinical knowledge but also cultivate essential medical humanities skills, such as empathy, communication, and professionalism.

### Knowledge Management

Artificial Intelligence (AI) has the potential to profoundly enhance students' capacity to classify, retrieve, and organize vast repositories of medical knowledge, thereby significantly improving learning efficiency. The medical field is characterized by its breadth and complexity, encompassing a wide spectrum of interconnected disciplines. AI serves as an invaluable tool in aiding medical professionals to effectively manage and utilize this vast pool of information, ultimately enhancing the quality and efficiency of healthcare delivery.

AI also facilitates the analysis and management of diverse medical data, including patient records, medical imaging, and laboratory results. By leveraging these capabilities, AI enhances the accuracy of diagnostic and therapeutic processes, empowering physicians to make more informed clinical decisions. One notable innovation in this domain is the integration of AI-driven courses based on knowledge graph technology, which has quietly revolutionized medical education. Within this framework, instructors and students collaborate to construct medical knowledge graphs, systematically organizing complex medical knowledge and uncovering the intricate interrelationships among its various components. This collaborative process not only sharpens students' logical and analytical thinking skills but also equips educators with actionable insights derived from the data generated during the graph-building activities, enabling more precise and effective instructional approaches.

In addition to its educational applications, AI can be harnessed to develop and implement robust medical knowledge management and sharing platforms. These platforms empower medical

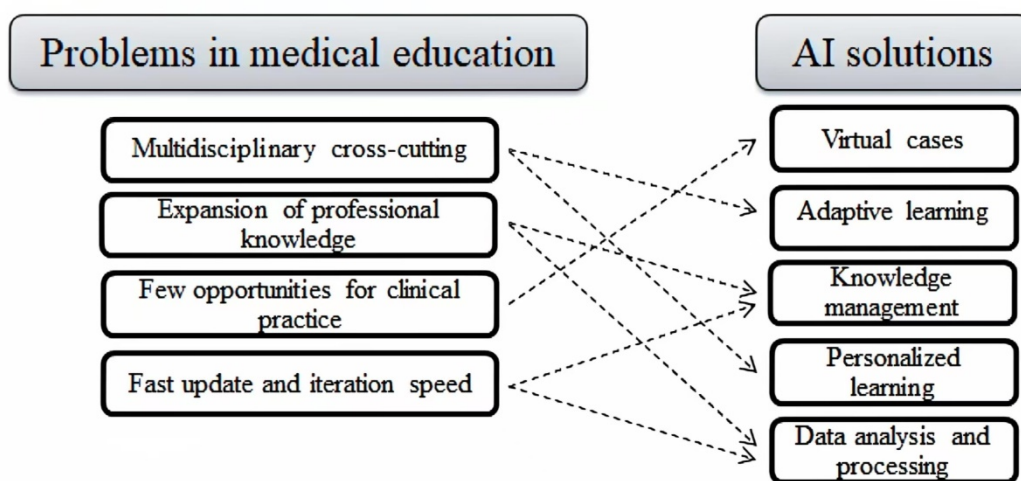


Figure 1: Problems in medical education and AI solutions.

professionals to efficiently share and access critical knowledge and experiential insights. Utilizing advanced technologies such as natural language processing, machine learning, and big data analytics, these platforms can intelligently recommend and filter relevant medical information tailored to the unique needs and interests of individual users. Such advancements greatly enhance both the dissemination and the quality of medical knowledge, fostering a more interconnected and informed medical community.

### Personalized Learning

AI offers transformative potential in designing personalized learning plans by analyzing students' learning records, performance metrics, and feedback. Leveraging advanced technologies such as natural language processing, machine learning, and big data analytics, AI facilitates the creation of tailored educational strategies that address the unique needs of individual learners. This approach significantly enhances the effectiveness and efficiency of medical education, enabling students to master complex medical knowledge with greater precision.

AI can dynamically recommend learning content and methodologies that align with learners' specific behaviors, abilities, and interests. For instance, in the domain of medical knowledge acquisition, AI systems can adjust both the content and its level of difficulty based on a learner's progress and comprehension levels, thereby optimizing the learning process and improving overall outcomes.

Furthermore, AI provides an array of personalized learning tools and resources to support medical education. These include customized problem sets and detailed answer explanations, as well as advanced features such as voice recognition and text-to-speech conversion tools. By employing these technologies, learners can deepen their understanding of complex concepts, effectively assimilating medical knowledge and enhancing their academic performance.

### Data Analysis and Processing

Data analysis and processing represent areas where Artificial Intelligence (AI) demonstrates unparalleled strengths. By enabling the rapid evaluation of extensive medical datasets, AI empowers medical students and professionals alike to derive actionable insights and provide personalized medical recommendations. Key applications of AI in this domain include, but are not limited to, the following areas:

#### Clinical Decision Support

AI employs sophisticated machine learning algorithms to analyze vast amounts of clinical data, thereby assisting physicians in formulating more precise diagnostic and therapeutic decisions.

This capability not only enhances clinical accuracy but also streamlines decision-making processes.

#### Imaging Analysis

AI excels in the analysis of medical imaging data, facilitating the identification of diseases and abnormalities with remarkable precision. By augmenting diagnostic accuracy, AI plays a pivotal role in improving early detection and timely intervention in patient care.

#### Genomic Analysis

Through the application of advanced big data analytics, AI enables the interpretation of complex genomic data. This allows for the identification of potential disease risks in patients, paving the way for personalized medicine and predictive healthcare strategies.

#### Medical Prognosis

AI is capable of analyzing historical patient records and other related medical datasets to forecast future health conditions. These predictive insights empower physicians to implement preventative measures and devise proactive therapeutic interventions, thereby improving patient outcomes.

#### Healthcare Management

AI contributes significantly to the operational efficiency of healthcare institutions by analyzing their management processes and resource allocation. This optimizes resource utilization while simultaneously improving the overall quality of healthcare services provided.

In recent years, the integration of AI technologies into medical education has advanced at an unprecedented pace. With its multifaceted advantages, AI promises to drive transformative changes in medical education, fostering a more efficient, precise, and personalized learning experience for future medical professionals.

## PROSPECTS

Artificial Intelligence (AI) undoubtedly offers innovative and transformative solutions for addressing longstanding challenges in medical education. However, several critical issues persist in its practical implementation, warranting closer examination and resolution.

#### Virtual Patient Cases

##### Authenticity Issues

Despite their utility, virtual patient cases cannot fully replicate the tangible experience of interacting with real patients, particularly in the development of complex doctor-patient communication skills. Furthermore, the integrity and accuracy of virtual case data may be compromised if improperly modified by educators or learners. This highlights the necessity for those involved

in designing virtual patient cases to possess a high degree of professional expertise and extensive practical experience to ensure the authenticity and reliability of these tools.

### Hardware and Software Issues

The usability of software systems, the intuitiveness of user interfaces, and potential physical discomfort—such as dizziness or nausea—caused by Virtual Reality (VR) equipment can significantly influence the acceptance of these technologies by students and educators alike. These limitations may adversely impact the overall learning experience and effectiveness, thus requiring careful consideration and refinement in design and implementation.

### Data Ethics Issues

The use of virtual patient cases must strictly adhere to local regulations and ethical guidelines. This includes obtaining approval from regulatory bodies for the utilization of clinical data and ensuring that patient consent has been granted for data usage. These legal and ethical considerations are paramount and warrant substantial attention to ensure compliance and safeguard patient privacy.

### Personalized Learning

#### Educational Equity Issues

Adaptive learning systems may inherit biases embedded within large-model training datasets, potentially resulting in a preferential focus on specific knowledge areas or perspectives. Such biases present significant challenges to maintaining equity in medical education. Furthermore, the hardware and network infrastructure required to support personalized learning may exacerbate existing disparities in the distribution of educational resources, particularly in underprivileged or resource-limited settings.

#### Side Effects of Technological Supremacy

While adaptive learning systems promote independent and individualized learning, they may inadvertently hinder the cultivation of essential interpersonal skills such as teamwork and communication—critical attributes for medical professionals. Additionally, these systems demand a higher degree of self-discipline from learners, potentially placing undue pressure on students who may struggle with self-regulation.

### Algorithm Ethics Issues

The ethical implications of algorithms used in learning analytics are multifaceted, encompassing data collection ethics, algorithmic operational ethics, and the ethics of algorithmic evaluation processes. Personalized learning analytics serve as the foundation for recommending individualized learning resources. However, if comprehensive data on learners' characteristics, abilities, and

core competencies cannot be accurately obtained, the resulting algorithms may suffer from significant biases, undermining the reliability and fairness of personalized learning systems.

Addressing these multifaceted issues and challenges necessitates sustained efforts through technological innovation, the establishment of robust policies, the refinement of educational practices, and rigorous ethical oversight. Effective strategies include fostering interdisciplinary integration within medical education, implementing continuous updates and iterative enhancements to digital hardware and software systems, and optimizing the performance and reliability of AI-driven large-model algorithms.

Currently, domestic research on the application of AI in medical education lacks a clear strategic focus, faces considerable technological barriers, and demonstrates limited practical application. Future efforts should prioritize refining theoretical frameworks and models, addressing technical challenges, and enhancing the widespread adoption and implementation of AI-driven adaptive learning systems in medical education. By doing so, these initiatives can pave the way for a more equitable, effective, and transformative educational landscape.

## CONCLUSION

"New Medical Sciences" represents a crucial transformation in medical education, responding to the evolving demands of the field and aiming to solve complex medical challenges through interdisciplinary integration. The rapid development of Artificial Intelligence (AI), particularly general-purpose systems like ChatGPT, has introduced both opportunities and challenges for medical education. Key issues facing the field include difficulties in integrating interdisciplinary knowledge, the overwhelming growth of medical information, limited clinical practice opportunities, and the need for lifelong learning in response to the fast-paced evolution of medical knowledge. AI applications in medical education include virtual case simulations to improve practical skills, adaptive learning systems that tailor content to student progress, knowledge management tools to organize vast amounts of medical data, personalized learning to meet individual needs, and data analytics supporting clinical decisions, medical imaging, and genomics. Despite the promise of AI, challenges such as the authenticity of virtual cases, educational equity, over-reliance on technology, and algorithmic bias remain. Hence, optimizing AI technology, refining policies, and integrating traditional educational methods are essential to advancing "New Medical Sciences" while addressing potential risks and challenges.

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## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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