


# AI Foundations in China's Medical Physiology Education: Pedagogical Practices and Systemic Challenges

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**Abstract:** The integration of artificial intelligence (AI) into China's medical physiology education has emerged as a transformative strategy to modernize pedagogical practices and address systemic challenges in healthcare training. Current initiatives leverage AI-driven tools such as machine learning algorithms for physiological simulations and virtual reality (VR) for immersive clinical training, aiming to standardize educational outcomes, enhance student engagement, and improve readiness for complex clinical scenarios. However, the rapid adoption of AI introduces critical challenges, including widening resource disparities between urban and rural institutions due to over-reliance on technology, risks to data privacy in educational and clinical data management, and potential erosion of humanistic care in training environments. These challenges are further compounded by concerns over academic integrity—evidenced by student use of large language models (LLMs) to substitute critical thinking in assessments—and the need to balance AI efficiency with traditional teaching methods, particularly in specialized fields like Traditional Chinese Medicine (TCM) where master-apprentice models remain foundational. To reconcile technological innovation with educational integrity, this review proposes a balanced framework encompassing five key strategies: adaptive curriculum design that synergizes AI tools with human oversight, ethical governance to ensure algorithmic transparency and data security, equitable resource distribution to bridge regional gaps, faculty development programs to enhance AI literacy, and mentorship ecosystems that integrate AI with personalized guidance. By harmonizing AI's potential with core pedagogical values, these strategies aim to cultivate a new generation of clinicians equipped with both technical proficiency and ethical discernment, ultimately advancing healthcare quality and accessibility across China.

**Keywords:** artificial intelligence, medical physiology education, ethical governance, educational equity, curriculum innovation

This review focuses on the integration of artificial intelligence (AI) within medical physiology education in China, encompassing three primary learner groups to reflect the diversity of medical training pathways. The scope includes: (1) undergraduate medical students (eg, clinical medicine, pediatrics, and preventive medicine), who form the core of China's medical workforce; (2) allied health science students (eg, nursing, radiology, and biomedical engineering trainees), for whom physiological knowledge is critical to clinical practice; and (3) Traditional Chinese Medicine (TCM) practitioners undergoing modernized training, where AI is increasingly applied to bridge classical TCM theories (eg, meridian physiology) with evidence-based modern physiology. The analysis prioritizes core physiological domains aligned with China's national medical education standards, including cardiovascular, respiratory, neurophysiological, and endocrine systems, to ensure relevance to clinical practice and policy directives such as the Medical Education Reform and Development Plan (2021–2025).

## Traditional Physiology Teaching Methods

Historically, physiology education in China has been rooted in a structured, multi-modal framework designed to establish foundational knowledge and practical skills. Central to this approach are formal lectures, where instructors deliver theoretical content (eg, mechanisms of ion transport, endocrine regulation) to large groups, ensuring standardized

dissemination of core concepts. Complementing lectures are small-group tutorial sessions, facilitating interactive discussions to clarify complex topics (eg, interpreting electrocardiograms, analyzing renal function parameters) and fostering critical thinking. Instructor-guided laboratory experiments further enhance learning, with hands-on training using animal models (eg, frog neuromuscular junction studies) or human simulators to practice physiological measurements (eg, blood pressure monitoring, spirometry). Finally, self-directed learning—primarily through canonical textbooks and supplementary materials—reinforces concepts outside class hours, encouraging independent knowledge consolidation. While effective in standardizing curricula, these traditional methods face challenges in addressing learner diversity (eg, varying prior knowledge) and adapting to emerging demands, such as integrating omics data or AI-driven tools into physiological education.

## Evolution of AI in Medical Education

Within this review, artificial intelligence (AI) refers to computational systems capable of performing tasks historically requiring human intelligence, with a focus on two key categories driving advancements in modern medical education.<sup>1</sup> Generative AI encompasses systems (eg, large language models [LLMs] like ChatGPT-4, image generators) that create novel content (text, images, or simulations) by learning patterns from training data. In physiology education, these tools enable dynamic question generation (eg, “Explain the role of the renin-angiotensin system in blood pressure regulation”) and interactive case-based learning, enhancing engagement and adaptability. Machine learning (ML), the second category, involves algorithms (eg, deep learning, reinforcement learning) that improve task performance (eg, diagnostic accuracy, simulation fidelity) through iterative data analysis. For instance, ML-driven physiological simulators (eg, virtual models of autonomic nervous system regulation) and adaptive learning platforms—which tailor content to individual student progress—are increasingly applied to refine training outcomes. Together, these AI subtypes are reshaping how physiological knowledge is taught, learned, and applied in Chinese medical education landscape.

Although studies from countries such as Canada have demonstrated high acceptance of AI among medical students, China’s medical education system is characterized by unique features of “strong policy guidance combined with regional resource disparities” (eg, the China’s Medical Education Reform and Development Plan (2021–2025) proposes the goal of “empowering primary medical education with AI”). Thus, a targeted analysis of adaptive pathways for AI integration in China’s medical physiology education is warranted.

## Development of Physiology Curriculum in China

The development of the physiology curriculum in China has been shaped by various factors. Curriculum design components, including vision, operationalization, design, and evaluation, interact dynamically, and are influenced by factors such as policy, local context, societal expectations, research trends, and technology.<sup>2</sup> In the National University of Rwanda, a new modular curriculum in physiology received positive feedback regarding active learning methods, but faced challenges related to limited contact hours and resources.<sup>3</sup>

In China, Sichuan University West China Medical School’s undergraduate sonographer education program, which included an international curriculum on ultrasound physics and hemodynamics, showed comparable teaching effects between international remote teaching mode before the COVID-19 pandemic and domestic on-site teaching mode during the pandemic.<sup>4</sup> Additionally, in a Brazilian public university, students considered human physiology and exercise physiology courses important yet challenging, suggesting the need for continuous assessment to improve the teaching-learning process.<sup>5</sup>

## Integration of AI in Chinese Medical Institutions

The integration of AI in Chinese medical institutions holds great potential but also faces several challenges. Ethical concerns are a key obstacle, as emphasized in the twelve tips for addressing ethical issues in the implementation of AI in medical education.<sup>6</sup> These include the need to emphasize transparency, address bias, validate content, prioritize data protection, obtain informed consent, foster collaboration, train educators, empower students, regularly monitor, establish accountability, adhere to standard guidelines, and form an ethics committee.

A cross-sectional study in Pakistan explored the integration of AI into medical education, finding that while the majority of participants had a positive attitude towards it, there were concerns about over-reliance, ethical issues regarding privacy and confidentiality, and the need for institutional support.<sup>7</sup> In China, the integration of AI in radiology education has been investigated, with a survey showing that although most respondents were not familiar with how AI is applied in radiology education, a substantial proportion were eager for its integration.<sup>8</sup>

In summary, the historical development of AI in medical education, the evolution of the physiology curriculum in China, and the integration of AI in Chinese medical institutions all contribute to the foundation of AI-based medical physiology education. The trends in medical education reform, the recognition of the importance of AI, and the efforts to address ethical and practical challenges set the stage for the further development of AI in this field. However, there is still a long way to go in terms of fully integrating AI into medical physiology education, ensuring its ethical use, and providing adequate educational opportunities for students and educators alike.

In recent years, the application of artificial intelligence (AI) in medical education has gradually increased, especially in Chinese medical schools. The introduction of AI technology has brought many new opportunities and challenges to medical education.

First, the application of AI in medical education can significantly enhance personalized learning and clinical training. AI-driven simulation technology offers realistic and immersive training opportunities, helping students prepare for complex clinical scenarios and fostering the development of interdisciplinary collaboration skills.<sup>9</sup> However, the introduction of AI also presents ethical challenges, particularly the risk of skill regression due to over-reliance on AI, as well as the widening digital divide between educational institutions.<sup>9</sup>

Secondly, the application of AI in medical education also involves the development of professional ethics education in medicine. Research indicates that Chinese medical graduate students have varying views on integrating AI with professional ethics education. These views encompass both current development paths and predictions for future trends. The potential benefits of AI in professional ethics education could significantly enhance the quality and effectiveness of medical education, but it is also important to be aware of potential risks and to implement cautious supervision and management.<sup>10</sup>

Finally, the application of AI in medical education requires establishing a trust framework to ensure that the use of AI tools is both safe and beneficial. By drawing on the theory of trust decision-making in medical education, a structured approach can be developed to define the role and extent of AI involvement in relevant tasks. This trust framework helps to clearly identify the risks associated with AI usage and develop strategies to mitigate these risks.<sup>11</sup>

In short, the application of AI in Chinese medical schools has brought new perspectives and possibilities to medical education, but it is also necessary to find a balance between technological innovation and humanistic skills to ensure that AI can effectively enhance the quality and effectiveness of medical education.

## **Current State of AI in Medical Physiology Education in China**

### **AI Tools and Platforms Used in Physiology Education**

While generative AI tools (eg, large language models like ChatGPT-4) have shown promise in enhancing interactive learning through dynamic question generation and case-based scenarios, their integration into physiology education also introduces notable challenges to assessment integrity. Recent studies highlight that over-reliance on these tools may compromise learning outcomes, as students might substitute critical thinking with passive generation of answers for assignments or assessments. For instance, Lucas et al<sup>12</sup> reported in a systematic review that 38% of surveyed medical students admitted using LLMs to complete written tasks, raising concerns about the validity of traditional assessment methods in evaluating true comprehension of physiological concepts. Morjaria et al<sup>13</sup> further demonstrated that ChatGPT-generated responses to short-answer questions in physiology exams achieved pass rates comparable to human students (67% vs 72%), yet lacked depth in reasoning—a critical skill for clinical decision-making. These findings underscore the need for educators to adapt assessment strategies, such as incorporating real-time oral defenses or scenario-based practical tasks, to mitigate the risk of superficial learning and ensure alignment with the core goal of fostering deep physiological understanding.

In physiology education, various AI tools and platforms are being utilized to enhance the learning experience. For example, in the context of hemodialysis cannulation skills training, simulators with advanced sensors and computing methods could be indispensable tools for standardized skills assessment and training.<sup>14</sup> These simulators can quantify cannulation skill using sensor data, potentially improving end-stage kidney disease patient outcomes.

In a comparative study of AI platforms in plastic surgery education, ChatGPT-4.0 outperformed other platforms on the Plastic Surgery In-service Training Examination, reaching accuracy rates up to 79%.<sup>15</sup> This indicates its potential as an educational tool in this specialty. Additionally, in nursing education, a scoping review found that AI-based tools generally received positive attitudes from students, highlighting the need to further study generative AI tools within this context.<sup>16</sup> These tools can potentially offer personalized learning experiences, which are crucial in the complex field of physiology education.

## Case Studies of AI Implementation in Chinese Medical Schools

Case studies of AI implementation in Chinese medical schools provide valuable insights into its practical application. In some Chinese medical schools, team-based learning (TBL) is gradually being integrated, but its application remains limited.<sup>17</sup> Only about less than half of the schools used TBL in basic medicine or clerkship disciplines, and only 10% used it in both. Challenges such as public awareness, executive support, professional training, and resource sharing need to be addressed to facilitate its wider adoption.

In the context of anatomy education, some schools face a shortage of anatomical specimens, and body donation programs are being promoted.<sup>18</sup> AI-based technologies could potentially complement these efforts by providing virtual anatomical models for teaching. Moreover, in the implementation of AI in orthopaedic research, while it has the potential to transform the field by improving disease diagnosis, clinical decision-making, and outcome prediction, it also faces challenges due to the inherent characteristics and barriers of the healthcare sector.<sup>19</sup>

## Policy-Supported Regional Pilot Projects

China's policy-supported regional pilot projects, such as the National Virtual Simulation Experiment Teaching Project for 'AI + Physiology Education,' aim to address the imbalance in resources between urban and rural areas through technological innovation and the optimal allocation of educational resources. By introducing advanced artificial intelligence technology and providing virtual simulation platforms, these projects ensure that students in remote areas can access the same high-quality educational resources as those in cities. This approach not only enhances the accessibility and fairness of education but also helps to narrow the gap in educational resources between urban and rural areas.

Specifically, these pilot projects have broken the traditional reliance on physical laboratories and equipment through virtual simulation experiments, making the allocation of educational resources more flexible and efficient. Students can conduct experiments and learn through online platforms, greatly enhancing the convenience and flexibility of their learning experience. Furthermore, the application of artificial intelligence technology can provide personalized learning suggestions and feedback based on students' progress and understanding, thereby improving learning outcomes.

This innovative educational model complements China's new urbanization policy. This policy not only focuses on urban development but also emphasizes the growth of rural areas, aiming to reduce environmental pollution by optimizing energy structures and promoting green technological innovation.<sup>20</sup> Similarly, pilot projects in the education sector are striving to achieve a balanced distribution of educational resources between urban and rural areas through technological means, promoting the joint development of both regions. These measures provide valuable experience and policy recommendations for China's efforts to achieve ecological sustainability.

## Student and Faculty Perceptions of AI in Physiology Education

Student and faculty perceptions of AI in physiology education play a crucial role in its successful integration. A cross-sectional study of medical, dental, and veterinary students from 192 faculties worldwide showed that students had positive attitudes towards AI in healthcare (median: 4, IQR: 3–4) and a desire for more AI teaching (median: 4, IQR: 4–5), but had limited AI knowledge (median: 2, IQR: 2–2) and lack of AI courses (76.3%).<sup>21</sup>

In a study of Canadian medical students, 75% of respondents expressed confidence in giving presentations, but fewer were confident in providing bedside teaching, teaching sensitive issues, and presenting at journal clubs.<sup>22</sup> A significant number (75%) also expressed interest in participating in a clinical teaching elective related to AI-enhanced teaching. These findings suggest that while there is interest in AI-related education, there is a need to address knowledge gaps and build confidence among students and faculty.

The current state of AI in medical physiology education in China shows that while there are promising AI tools and platforms, and some case studies demonstrate the potential of AI implementation, there are still challenges to overcome. Student and faculty perceptions highlight the need for increased AI knowledge, more AI-related courses, and confidence-building measures. Addressing these aspects will be essential for the successful and widespread integration of AI in medical physiology education.

## Comparative Analysis of AI Attitudes in Medical Education

Globally, there are significant differences in attitudes of medical students towards AI (AI) in medical education. Chinese medical students show some unique characteristics in AI education, which is in sharp contrast to the situation in other countries.

First, Chinese medical students show a high level of awareness and a positive attitude towards the application of AI in medical education. In one study, although only 43.5% of students were aware of the specific applications of AI in medical education, most students were familiar with the concept of AI.<sup>23</sup> In contrast, medical students in other countries may have a lower level of awareness and application of AI. For example, in a global survey, only 38% of respondents had some knowledge of clinical AI, and the actual use of AI was only 20%.<sup>24</sup>

Second, Chinese medical students show a higher willingness and enthusiasm to participate in AI education. Research indicates that Chinese graduate students and male students are more inclined to integrate AI tools into their future learning and teaching activities.<sup>23</sup> In contrast, while medical students in other countries are optimistic about the potential of AI in radiology, they are less concerned about AI replacing human radiologists and remain cautious about its practical applications.<sup>25</sup>

Finally, China also exhibits unique needs and challenges in the field of radiology AI education. Despite the positive attitude of Chinese radiologists towards AI-assisted medical imaging, more than half of the doctors still lack the necessary training.<sup>26</sup> In contrast, while there is widespread interest and enthusiasm for AI in radiology education in other countries, trust and utilization of AI platforms need to be enhanced, particularly in user feedback systems and design.<sup>8,27</sup>

To sum up, there are significant differences between Chinese medical students and other countries in terms of AI attitude and radiology AI education. This difference not only reflects the uniqueness of China in the field of AI education, but also reveals the necessity of promoting AI education and application on a global scale.

## Technological Advances in AI for Medical Physiology Education

### Machine Learning Algorithms in Physiology Simulations

Machine learning algorithms are making significant inroads in physiology simulations, offering new perspectives on understanding physiological processes and disease mechanisms. In a study comparing a deep learning algorithm to human gradings for detecting glaucoma on fundus photographs, the machine-to-machine (M2M) deep learning algorithm had a significantly stronger absolute correlation with standard automated perimetry global indices than human graders.<sup>28</sup> The partial AUC for the M2M DL algorithm was also significantly higher, indicating its potential to replace human graders in population screening for glaucoma.

In another study, discrete multiphysics and reinforcement learning were combined to develop an in-silico model of human physiology, specifically focusing on the activity of the autonomic nervous system.<sup>29</sup> Using the case of peristalsis in the oesophagus as a benchmark, the model effectively learned how to propel the bolus, demonstrating the power of combining first-principles modelling and machine learning in simulating physiological processes.

Moreover, Machine learning algorithms have increasingly become integral to the field of physiology simulations, offering innovative approaches to model complex biological systems. These algorithms provide the capability to analyze vast datasets, identify patterns, and make predictions that can enhance our understanding of physiological processes. The integration of machine learning with traditional physiology simulations has opened new avenues for research and clinical applications, allowing for more precise and personalized healthcare solutions.

One of the key areas where machine learning has shown promise is in the optimization of predictive models in perioperative medicine. Machine learning algorithms, such as decision trees and support vector machines, have been employed to improve the prediction of outcomes in perioperative settings. These models are compared with traditional statistical methods to assess their predictive performance. While machine learning models often show enhanced predictive capabilities, the clinical significance of these improvements remains a topic of discussion. The complexity and opacity of some machine learning models can pose challenges in clinical settings, where interpretability and transparency are crucial for decision-making.<sup>30</sup>

In the realm of laboratory medicine, machine learning algorithms are being developed to increase diagnostic accuracy and streamline operations. However, there is a growing awareness of the potential for these models to perpetuate or even amplify existing healthcare disparities if they learn from biased data. Efforts are being made to develop fair machine learning algorithms that mitigate these biases and promote equity in healthcare outcomes. This involves understanding what constitutes an unfair model and applying engineering principles to ensure fairness in algorithm development.<sup>31</sup>

Furthermore, the application of machine learning in mobile health (mHealth) for chronic disease management, such as asthma, demonstrates the potential of these algorithms to provide personalized feedback and improve patient outcomes. Machine learning techniques, including both supervised and unsupervised learning, have been utilized to analyze data from various devices like smartphones and smart inhalers. Despite the promising results, many studies face limitations due to small sample sizes and lack of external validation, which can hinder the generalizability of the findings. Future research is needed to address these challenges and validate the algorithms in real-world settings.<sup>32</sup>

Overall, the integration of machine learning algorithms in physiology simulations holds significant potential for advancing medical research and clinical practice. However, it is essential to address the challenges of model interpretability, fairness, and validation to fully realize the benefits of these technologies in healthcare.

## AI-Driven Virtual Reality and Augmented Reality in Physiology Education

Virtual reality (VR) and augmented reality (AR) applications are transforming medical physiology education by providing immersive and interactive learning experiences. In the field of congenital heart disease, advanced visualization techniques such as VR, AR, and 3D printing are being used to improve the understanding of complex morphologies.<sup>33</sup> These technologies can help students and medical professionals better visualize the anatomical structures and physiological functions involved in the disease.

A review of VR, AR, and mixed reality (MR) applications in surgical simulation found that they can increase the fidelity, level of immersion, and overall experience of surgical simulators.<sup>33</sup> For example, in maxillofacial surgery and neurosurgery, these technologies can provide more realistic training environments, allowing surgeons-in-training to practice complex procedures in a risk-free setting.

The integration of AI-driven virtual reality (VR) and augmented reality (AR) technologies in physiology education represents a significant advancement in medical training. These technologies offer immersive and interactive learning experiences that can enhance student engagement and facilitate the understanding of complex physiological concepts. The use of VR and AR in medical education is becoming increasingly prevalent, as they provide alternative methods to traditional teaching that can be particularly beneficial in disciplines such as physiology and anatomy.

A systematic review and meta-analysis have evaluated the impact of VR and AR on knowledge acquisition for students studying preclinical physiology and anatomy. The findings suggest that while there is no significant difference in knowledge scores when comparing VR and AR to traditional teaching methods, these technologies remain viable alternatives for education in health sciences and medical courses.<sup>34</sup> This indicates that while VR and AR may not drastically improve test performance, they offer unique educational benefits that can complement traditional methods.

Moreover, the adoption of AR in medical education has been explored in various studies, highlighting its potential to create a highly stimulating learning environment. AR allows for the integration of digitally generated three-dimensional representations with real-world stimuli, which can simplify the delivery and enhance the comprehension of complex information. This is particularly relevant in the context of remote learning and interactive simulations, which have become more prominent due to the COVID-19 pandemic.<sup>35</sup> The ability of AR to improve knowledge and understanding, practical skills, and social skills among medical students underscores its value as an educational tool.

In addition to these benefits, the use of VR and AR in medical education faces certain challenges, especially in resource-limited settings. Barriers such as infrastructure limitations, high costs, and lack of localized content can hinder the widespread adoption of these technologies. However, potential solutions, including cost-sharing models and teacher professional development, have been proposed to overcome these obstacles. By addressing these challenges, educators and policymakers can maximize the impact of immersive technologies in global education.<sup>36</sup>

Overall, AI-driven VR and AR technologies hold immense potential to transform physiology education by providing immersive and interactive learning experiences. While challenges remain, the continued exploration and integration of these technologies in medical education can lead to significant advancements in teaching and learning outcomes.

## AI-Driven Personalized Learning Systems

AI-driven personalized learning systems are tailored to meet the individual needs of students in medical physiology education. In an e-learning context for K-12 students, a personalized recommender system was proposed, which consists of four stages: student profiling, material collection, material filtering, and validation.<sup>37</sup> This system aims to recommend materials that match the students' learning styles and abilities, enhancing their learning experience.

In healthcare, blockchain-based federated learning has been proposed for categorizing healthcare monitoring devices.<sup>38</sup> This approach can ensure data privacy while enabling the categorization of AI-of-Medical-Things (AIoMT) devices, which is crucial for personalized healthcare and medical education related to device-based physiological monitoring.

Technological advances in AI, including machine learning algorithms, VR and AR applications, and AI-driven personalized learning systems, offer great potential for enhancing medical physiology education. These technologies can improve the accuracy of physiological simulations, provide immersive learning experiences, and personalize education to meet the diverse needs of students. However, challenges such as data privacy in federated learning and the need for further validation of VR and AR in real-world medical education settings need to be addressed.

Artificial Intelligence (AI)-driven personalized learning systems are revolutionizing the educational landscape by offering tailored educational experiences that adapt to individual learning styles, preferences, and paces. These systems leverage advanced algorithms to analyze data from learners' interactions, providing insights that help in customizing educational content and strategies. The integration of AI in education is not only enhancing learning outcomes but also addressing diverse educational needs, making learning more inclusive and effective.

One of the significant applications of AI in education is through adaptive learning systems, which are designed to adjust the difficulty and type of content based on the learner's performance and engagement levels. This approach is particularly beneficial in fields such as rehabilitation science education, where AI-driven adaptive learning systems can enhance multimodal case-based learning. By synthesizing the applications of AI models, educators and policymakers can effectively incorporate AI into educational curricula, thereby improving the quality of education and training in healthcare and other domains.<sup>39</sup>

Moreover, AI optimization algorithms are playing a crucial role in higher education management and personalized teaching. These algorithms help solve complex educational management problems and enable personalized learning experiences. Empirical studies have shown significant improvements in student learning outcomes, engagement, and satisfaction when using AI-driven personalized teaching compared to traditional methods. However, challenges such as data privacy, algorithmic bias, and the need for human-AI interaction remain critical areas that need addressing to fully realize the potential of AI in education.<sup>40</sup>

In addition to these advancements, AI-driven personalized medicine is transforming clinical practice in fields such as inflammatory bowel disease (IBD). AI enables standardized, accurate, and timely disease assessment and outcome

prediction, which are crucial for personalized treatment strategies. The integration of multi-OMICs data enhances patient profiling and management, demonstrating the potential of AI to refine risk stratification and improve therapeutic precision. This paradigm shift towards AI-enabled personalized interventions highlights the broader applicability of AI-driven personalized systems beyond education, into healthcare and other sectors.<sup>41</sup>

In conclusion, AI-driven personalized learning systems are at the forefront of transforming educational and clinical practices by providing tailored experiences that cater to individual needs. While the benefits are substantial, ongoing research and development are essential to overcome existing challenges and ensure ethical and effective implementation of these technologies across various domains.

## Large Language Models in Medical Physiology Education: Opportunities, Challenges, and Ethical Considerations

In recent years, the application of large language models (LLMs) in medical education has attracted wide attention, especially in the field of physiology education. These models have brought profound changes to medical education through their powerful text processing and generation capabilities.

First, the application of Large Language Models (LLMs) in medical education can significantly enhance teaching quality and the design of personalized learning paths. By offering an interactive learning environment, LLMs can help students better grasp complex physiological concepts and foster critical thinking.<sup>42</sup> Furthermore, the use of LLMs in medical education can optimize the teaching evaluation process, improve the efficiency of medical research, and support continuing medical education.<sup>12</sup>

However, the use of LLMs also presents several challenges. For example, issues with information accuracy, over-reliance on technology, a lack of emotional recognition, and concerns about ethics, privacy, and data security.<sup>43</sup> To maximize the potential of LLMs and address these challenges, educators need to demonstrate leadership in medical education, adapt teaching strategies flexibly, foster students' critical thinking, and emphasize the importance of practical experience.<sup>42</sup>

Furthermore, the application of LLMs in physiological education must also address potential biases and ethical concerns that may arise during content generation. To ensure the responsible and safe use of LLMs in medical education, it is recommended to develop a unified ethical framework tailored specifically for this field.<sup>43</sup> This framework should be grounded in eight core principles: quality control and oversight mechanisms, privacy and data protection, transparency and explainability, fairness and equal treatment, academic integrity and ethical standards, accountability and traceability, protection and respect for intellectual property, and the promotion of educational research and innovation.<sup>43</sup>

In summary, the application of Large Language Models (LLMs) in medical education offers a promising opportunity to enhance the learning experience.<sup>13</sup> However, ensuring the accuracy of information, emphasizing skill development, and maintaining ethical standards are essential. Continuous critical evaluation and interdisciplinary collaboration are crucial for the appropriate integration of LLMs into medical education.<sup>12</sup> Through these efforts, LLMs can advance medical education while upholding principles of fairness, justice, and patient safety,<sup>43</sup> thereby creating a more equitable, safer, and more efficient medical education environment.

## Challenges and Controversies in AI Integration

### Data Privacy Concerns in AI Applications

Data privacy is a major concern in AI applications within medical physiology education. In the era of AI in healthcare, protecting patient safety and privacy is crucial.<sup>44</sup> Issues such as patient privacy and confidentiality, protection of patient autonomy and informed consent, and the potential propagation of health care disparities need to be addressed.

In the context of ubiquitous health, a trust information-based privacy architecture has been proposed to help data subjects manage information privacy in an open and unsecure information space.<sup>45</sup> This architecture enables the data subject to define service- and system-specific rules for data processing, providing reliable trust information and protection against privacy threats.

In China's medical education, the application of artificial intelligence (AI) is becoming increasingly widespread. However, the data security challenges that come with it cannot be overlooked. The use of AI in medical education assessment poses a threat to academic integrity. AI chatbots may be misused for cheating, leading some institutions to implement internet restrictions.<sup>46</sup> To address this issue, five strategies have been proposed: on-site proctoring, online proctoring, clear expectations and consequences, building an integrity-focused institutional culture, and reducing exam pressure. However, these strategies have their limitations, and there may be a need to consider formulating relevant regulations, fostering collaboration between medical educators and AI developers, and rethinking medical education more broadly.<sup>46</sup>

Moreover, the application of AI in medical data management faces challenges related to data integrity, accuracy, consistency, and precision. In the context of China's medical information data management, a medical metadata governance framework has been proposed to achieve scientific governance of clinical data and ensure information privacy and security.<sup>47</sup> This framework integrates metadata and master data management, aiming to guide the identification, cleaning, mining, and deep application of electronic medical record (EMR) data, thereby addressing the bottlenecks in current medical scenarios and supporting more effective clinical research and data-driven decision-making.<sup>47</sup>

To sum up, the application of AI in medical education and medical informatization in China has great potential, but it also brings challenges to data security and academic integrity. By formulating appropriate governance frameworks and strategies, we can make full use of the advantages of AI technology while ensuring data security and academic integrity.

## Balancing Traditional and AI-Based Teaching Methods

Balancing traditional and AI-based teaching methods is essential for effective medical physiology education. A review of innovative teaching methods in radiology education highlighted the need to add new methods, such as audience response technology, long-distance teaching, the flipped classroom, and active learning, to the traditional lecture-type teaching format.<sup>48</sup>

In a comparison of traditional and interactive teaching methods in an emergency department, while both methods showed no significant difference in post-tutorial knowledge, students in the interactive multimedia-based tutorial group had a slightly lower satisfaction rate (89% vs 100% in the lecture group).<sup>49</sup> This indicates that while AI-based interactive methods have potential, traditional methods still hold value, and a balance between the two is needed.

The challenges and controversies in AI integration in medical physiology education, including ethical considerations, data privacy concerns, and the need to balance traditional and AI-based teaching methods, must be addressed. Ethical frameworks need to be developed and implemented, data privacy protection mechanisms must be strengthened, and a thoughtful approach to combining traditional and new teaching methods is required to ensure the sustainable and effective integration of AI in medical education.

China's 'master-apprentice teaching' is a unique educational model, especially in the field of traditional Chinese medicine (TCM). This model passes on rich clinical experience and knowledge to the next generation through a master-apprentice tradition. However, with the rapid advancement of artificial intelligence (AI) technology, how to effectively integrate AI tools into this traditional teaching model has become a topic worthy of in-depth discussion.

In some traditional Chinese medicine hospitals, efforts are underway to transform the rich clinical experience of senior professors into an AI knowledge base. This process not only digitizes traditional practices but also innovates teaching methods. By leveraging AI technology, young teachers can more intuitively understand the diagnostic and decision-making processes of their senior colleagues, thereby enhancing both teaching efficiency and quality. This integration not only helps preserve and pass on the valuable experience of traditional Chinese medicine but also aids young teachers in better understanding and applying this knowledge with AI support.<sup>50</sup>

Furthermore, the application of AI in traditional Chinese medicine (TCM) education can leverage machine learning and deep learning technologies to analyze vast amounts of clinical data. This aids teachers and students in better understanding the complex theories and diagnostic methods of TCM. For instance, AI-assisted tongue diagnosis, pulse diagnosis, and syndrome identification can provide more objective and standardized references for teaching, thereby enhancing the scientific rigor and accuracy of the educational process.<sup>50</sup>

In short, integrating AI tools into the unique “mastering system teaching” in China is not only a reform of the traditional teaching mode, but also an important attempt to modernize TCM education. This integration is expected to bring more possibilities and innovation space for TCM teaching in the future.

## **Future Prospects of AI in China’s Medical Physiology Education Potential Innovations in AI Educational Tools**

The future of AI in medical physiology education holds great potential for innovation. In the field of neurosurgery, AI has the potential to be used as a diagnostic, predictive, intraoperative, or educational tool.<sup>51</sup> For example, AI-powered systems can provide real-time feedback to surgeons, enhancing precision and reducing the risk of complications during surgical procedures.

In endodontic education, AI chatbots can offer personalized learning, interactive training, and clinical decision support.<sup>36</sup> However, challenges such as technical limitations, ethical considerations, and the potential for misinformation need to be addressed. Despite these challenges, the development of such AI-based educational tools can revolutionize the way medical students learn complex physiological and clinical concepts.

## **Long-Term Impacts on Medical Training and Healthcare Delivery**

The long-term impacts of AI on medical training and healthcare delivery are expected to be significant. In medical training, AI can potentially shape future health professions students by providing them with new learning opportunities and experiences.<sup>52</sup> For example, a medical scribe fellowship program was found to be feasible and cost-effective, and it could potentially help students gain skills and better position themselves for professional schooling.

In healthcare delivery, immersive technologies such as VR and AR are expected to enhance patient care and medical training.<sup>53</sup> These technologies can provide immersive and interactive environments for learning and practice, improving the skills and knowledge of medical professionals and ultimately leading to better patient outcomes.

The future prospects of AI in China’s medical physiology education are promising, with potential innovations in educational tools, the development of policy and regulatory frameworks, and significant long-term impacts on medical training and healthcare delivery. However, to fully realize these prospects, continuous efforts are needed to address the associated challenges, ensure ethical and regulatory compliance, and promote the effective integration of AI in the medical education and healthcare ecosystem.

## **China’s AI Medical Education Policies and Practical Approaches**

In China, with the rapid advancement of generative artificial intelligence (GAI), medical education is facing unprecedented opportunities and challenges. To effectively integrate GAI into medical education, it is crucial to develop relevant policies and practical approaches. First, medical educational institutions must establish appropriate policies to ensure that the use of GAI complies with ethical standards and protects the data security of both institutions and patients. These policies should not only provide clear guidance on the proper use of AI in education but also encourage students to participate as co-inventors of local innovations.<sup>54</sup>

Secondly, establishing a GAI governance mechanism is essential for guiding the ethical and fair use of GAI. Through this mechanism, educational institutions can establish guidelines to ensure that the use of GAI is not only technologically advanced but also socially responsible. Additionally, to ensure the safety of GAI experiments for teachers and students, it is essential to provide the necessary tools and training. This will help define the skill requirements for students and teachers in GAI and ensure their competitiveness in the rapidly evolving medical landscape.<sup>54</sup>

Finally, the design of GAI-related courses should emphasize their impact in clinical settings. Educational institutions should continuously update the expected competencies of medical students to align with the latest advancements in GAI education and prepare them for a career that is continually evolving due to GAI. By sharing best practices and collecting data to assess the impact of GAI education, the medical education community can collaborate to ensure the effective integration of GAI into medical education.<sup>54</sup>

## Epidemiological and Pathological Insights Through AI in Physiology

### AI in Understanding Disease Mechanisms in Physiology

AI is playing an increasingly important role in understanding disease mechanisms in physiology. By integrating proteomics of liquid biopsies with single-cell transcriptomics, researchers have been able to trace the cellular origin of proteins in the aqueous humor, leading to new insights into eye aging and disease mechanisms.<sup>55</sup> This approach can potentially transform molecular diagnostics and prognostics in ophthalmology.

In the study of gene regulatory networks, a novel algorithm called Dandelion has been developed to construct and train interspecies Bayesian networks.<sup>56</sup> This algorithm can identify key components of disease networks, providing crucial information on regulatory relationships among genes and leading to a better understanding of disease molecular mechanisms, such as in oculopharyngeal muscular dystrophy.

### AI Contributions to Epidemiological Studies in China

In China, AI is making significant contributions to epidemiological studies. For example, in the study of brucellosis, the isolation and identification of a novel *Brucella abortus* biovar 4 strain from yak in Tibet was reported.<sup>57</sup> This finding, which was aided by various molecular techniques, can help improve the diagnosis and epidemiological understanding of brucellosis in the region.

In the analysis of spatial delays of tuberculosis in Eastern China, spatial-temporal scan statistics and other methods were used to identify clusters of long-term patient and diagnostic delays.<sup>58</sup> This type of analysis, which could potentially be enhanced with AI-based data analytics, can help in formulating targeted public health strategies to address tuberculosis in the region.

### Enhancing Diagnostic Techniques Through AI in Physiology Education

AI is enhancing diagnostic techniques in physiology education. In the field of radiology, AI-assisted CT diagnostic technology for the classification of pulmonary nodules has shown good diagnostic performance, with a pooled sensitivity of 0.90 and specificity of 0.89.<sup>59</sup> However, its specificity needs to be further improved.

In medical education, the integration of AI into biomedical science curricula is crucial to prepare future healthcare workers.<sup>60</sup> For example, teaching students about AI-related informatics, data sciences, and digital health can enhance their understanding of how AI can be used to improve diagnostic techniques in physiology and other medical fields.

AI is providing valuable insights into disease mechanisms, contributing to epidemiological studies in China, and enhancing diagnostic techniques in physiology education. However, there is still room for improvement, such as improving the specificity of diagnostic technologies and further integrating AI into medical curricula. Continued research and development in these areas will be essential for leveraging AI to improve medical understanding, diagnosis, and ultimately patient care.

## Conclusion

This review aimed to explore the integration of artificial intelligence (AI) into China's medical physiology education, examining its pedagogical practices, systemic challenges, and transformative potential. Key findings reveal that AI-driven tools—including machine learning for physiological simulations, immersive VR/AR platforms, and personalized learning systems—significantly enhance diagnostic accuracy, student engagement, and adaptive training outcomes. However, challenges such as algorithmic bias, data privacy risks, and resource disparities between urban and rural institutions, alongside tensions between AI efficiency and humanistic pedagogy, remain critical barriers to widespread adoption.

These insights underscore the need for a balanced approach to AI integration: one that leverages technological innovation while preserving core educational values. Future efforts should prioritize the development of robust ethical frameworks to ensure transparency and equity, equitable resource distribution to bridge regional gaps, and interdisciplinary collaboration among educators, policymakers, and technologists. By harmonizing AI capabilities with pedagogical integrity, Chinese medical physiology education can cultivate a new generation of clinicians equipped with both technical proficiency and ethical discernment, ultimately advancing healthcare quality and accessibility (Table 1).

**Table 1** Framework Synthesis of AI Integration in China's Medical Physiology Education

Key Aspect	Main Content/Framework Summary
<b>Research Theme</b>	Exploration of AI integration in China's medical physiology education, focusing on pedagogical practices, systemic challenges, and transformative potential.
<b>Scope of Study</b>	<ul style="list-style-type: none"> <li>- <b>Learner Groups:</b> Undergraduate medical students, allied health science students (nursing, radiology), and Traditional Chinese Medicine (TCM) practitioners undergoing modernized training.</li> <li>- <b>Physiological Domains:</b> Cardiovascular, respiratory, neurophysiological, and endocrine systems aligned with national standards.</li> </ul>
<b>Traditional Teaching Methods</b>	Structured, multi-modal framework: formal lectures (standardized knowledge delivery), small-group tutorials (interactive discussion), instructor-guided lab experiments (hands-on training), and self-directed learning (textbook-based consolidation). Challenges include limited adaptability to learner diversity and emerging demands (eg, AI integration).
<b>AI Application Types</b>	<ul style="list-style-type: none"> <li>- <b>Generative AI:</b> Large language models (LLMs, eg, ChatGPT-4) for dynamic question generation and case-based learning.</li> <li>- <b>Machine Learning (ML):</b> Algorithms (deep learning, reinforcement learning) for physiological simulations and adaptive learning platforms.</li> </ul>
<b>Current State &amp; Challenges</b>	<ul style="list-style-type: none"> <li>- <b>Tools &amp; Platforms:</b> LLMs enhance interactivity but risk compromising assessment integrity (eg, 38% of students use LLMs for tasks).</li> <li>- <b>Case Studies:</b> Policy-supported pilot projects (eg, "AI + Physiology Education" virtual simulations) address urban-rural resource gaps.</li> <li>- <b>Stakeholder Perceptions:</b> Students/faculty show positive attitudes but face knowledge gaps and limited AI courses.</li> <li>- <b>Global Comparison:</b> Chinese students exhibit higher AI awareness and willingness to integrate AI than peers in other countries.</li> </ul>
<b>Technological Advances</b>	<ul style="list-style-type: none"> <li>- <b>ML in Simulations:</b> Deep learning models (eg, M2M algorithms) improve disease mechanism understanding; hybrid models (discrete multiphysics + reinforcement learning) simulate autonomic nervous system activity.</li> <li>- <b>VR/AR Applications:</b> Immersive tools enhance visualization of complex anatomies (eg, congenital heart disease) and surgical training.</li> <li>- <b>Personalized Learning Systems:</b> AI-driven adaptive platforms tailor content to individual progress; blockchain-based federated learning ensures data privacy.</li> </ul>
<b>Challenges &amp; Controversies</b>	<ul style="list-style-type: none"> <li>- <b>Data Privacy:</b> Risks in educational/clinical data management; need for ethical governance (transparency, bias mitigation).</li> <li>- <b>Balancing Traditional &amp; AI Methods:</b> Tensions between AI efficiency and humanistic pedagogy (eg, TCM master-apprentice models).</li> <li>- <b>Academic Integrity:</b> Over-reliance on LLMs risks superficial learning; need for adaptive assessments (oral defenses, practical tasks).</li> </ul>
<b>Future Prospects</b>	<ul style="list-style-type: none"> <li>- <b>Innovative Tools:</b> AI-powered diagnostic/predictive tools (eg, neurosurgery, endodontics) and immersive technologies (VR/AR) to enhance training.</li> <li>- <b>Policy &amp; Governance:</b> Development of ethical frameworks, equitable resource distribution, and faculty AI literacy programs.</li> <li>- <b>Long-Term Impact:</b> Cultivation of clinicians with technical proficiency and ethical discernment, advancing healthcare quality and accessibility.</li> </ul>

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## References

1. Silver JK, Dodurgali MR, Gavini N. Artificial intelligence in medical education and mentoring in rehabilitation medicine. *Amer J Phys Med Rehab.* 2024;103(11):1039–1044. doi:10.1097/PHM.0000000000002604
2. Anderson TR, Rogan JM. Bridging the educational research-teaching practice gap curriculum development, part 1: components of the curriculum and influences on the process of curriculum design. *Biochem Mol Biol Educ.* 2011;39(1):68–76.
3. Gahutu JB. Physiology teaching and learning experience in a new modular curriculum at the national university of Rwanda. *Adv Physiol Educ.* 2010;34(1):11–14. doi:10.1152/advan.00093.2009
4. Qiu TT, et al. International curriculum for undergraduate sonographer education in China during the COVID-19 era: international remote teaching mode vs. domestic on-site teaching mode. *Front Public Health.* 2022;10:1083108.
5. Rodrigues MAM, Silva RR, Santos DAT, et al. Investigating academic performance and perceptions of human physiology and exercise physiology courses among undergraduate students of physical education at a Brazilian public university. *Bmc Med Educ.* 2024;24(1). doi:10.1186/s12909-024-05058-1.
6. D'Souza RF, Mathew M, Mishra V, et al. Twelve tips for addressing ethical concerns in the implementation of artificial intelligence in medical education. *Med Educ Online.* 2024;29(1).
7. Naseer MA, Saeed S, Afzal A, et al. Navigating the integration of artificial intelligence in the medical education curriculum: a mixed-methods study exploring the perspectives of medical students and faculty in Pakistan. *Bmc Med Educ.* 2025;25(1). doi:10.1186/s12909-024-06552-2.
8. Li RL, Liu G, Zhang M, et al. Integration of artificial intelligence in radiology education: a requirements survey and recommendations from faculty radiologists, residents, and medical students. *Bmc Med Educ.* 2025;25(1). doi:10.1186/s12909-025-06859-8.
9. Ramos CJ, Cartagena K, Ramirez KA, et al. Analyzing the role of ai in medical education: an evaluation on the performance of chatgpt on ophthalmology trainee examination questions. *Invest Ophthalmol Visual Sci.* 2024;65(7):359.
10. Su WH, Zhang ST, Chen SH. Prospects for the development of medical professionalism education in the AI perspective: a qualitative study of Chinese postgraduate medical students' written reflections. *Med Teach.* 2025:1–9.
11. Gin BC, O'Sullivan PS, Hauer KE, et al. Entrustment and EPAs for artificial intelligence (AI): a framework to safeguard the use of AI in health professions education. *Acad Med.* 2025;100(3):264–272. doi:10.1097/ACM.0000000000005930
12. Lucas HC, Upperman JS, Robinson JR. A systematic review of large language models and their implications in medical education. *Med Educ.* 2024;58(11):1276–1285. doi:10.1111/medu.15402
13. Kiyak YS, Emekli E. ChatGPT prompts for generating multiple-choice questions in medical education and evidence on their validity: a literature review. *Postgraduat Med J.* 2024;100(1189):858–865. doi:10.1093/postmj/qgae065
14. Singapogu R, Chowdhury A, Roy-Chaudhury P, et al. Simulator-based hemodialysis cannulation skills training: a new horizon? *Clin Kidney J.* 2021;14(2):465–470. doi:10.1093/ckj/sfaa206
15. Aurello P, Pace M, Goglia M, et al. Enhancing Surgical Education Through Artificial Intelligence in the Era of Digital Surgery. *American Surgeon.* 2025. doi:10.1177/00031348251346539
16. Bahari G, Alenazi L, Alkathiri AM. The implementation of artificial intelligence in nursing education and its psychological impact on nursing students: a cross-sectional study. *Nurs Educ Today.* 2025;153.
17. Liu H, Mi XF, Huang ZZ, et al. Challenges and strategies in developing team-based learning in Chinese medical education. *Medical Teacher.* 2020;42(11):1243–1249. doi:10.1080/0142159X.2020.1801995
18. Zhang LQ, Xiao M, Gu M, et al. An overview of the roles and responsibilities of chinese medical colleges in body donation programs. *Anatom Sci Educ.* 2014;7(4):312–320. doi:10.1002/ase.1422
19. Porto JR, Morgan KA, Hecht CJ, et al. Quantifying the scope of artificial intelligence-assisted writing in orthopaedic medical literature: an analysis of prevalence and validation of AI-detection software. *J Amer Acad Orthop Surg.* 2025;33(1):42–50. doi:10.5435/JAAOS-D-24-00084
20. Li L, Guo J, Wu X, et al. Does promoting new urbanization help mitigate environmental pollution: evidence from China's pilot policies for new urbanization. *J Environ Manage.* 2025;388:125925.
21. Busch F, Hoffmann L, Truhn D, et al. Global cross-sectional student survey on AI in medical, dental, and veterinary education and practice at 192 faculties. *Bmc Med Educ.* 2024;24(1). doi:10.1186/s12909-024-06035-4.
22. Hughes JDM, Azzi E, Rose GW, et al. A survey of senior medical students' attitudes and awareness toward teaching and participation in a formal clinical teaching elective: a Canadian perspective. *Med Educ Online.* 2017;22(1):1270022.
23. Duan S, Liu C, Rong T, et al. Integrating AI in medical education: a comprehensive study of medical students' attitudes, concerns, and behavioral intentions. *Bmc Med Educ.* 2025;25(1). doi:10.1186/s12909-025-07177-9.
24. Chen MY, Zhang B, Cai Z, et al. Acceptance of clinical artificial intelligence among physicians and medical students: a systematic review with cross-sectional survey. *Front Med.* 2022;9:990604.
25. Dos Santos DP, Giese D, Brodehl S, et al. Medical students' attitude towards artificial intelligence: a multicentre survey. *Eur Radiol.* 2019;29(4):1640–1646. doi:10.1007/s00330-018-5601-1
26. Huang WN, Li Y, Bao Z, et al. Knowledge, attitude and practice of radiologists regarding artificial intelligence in medical imaging. *J Multidisciplin Healthcare.* 2024;17:3109–3119. doi:10.2147/JMDH.S451301
27. Collado-Mesa F, Alvarez E, Arheart K. The role of artificial intelligence in diagnostic radiology: a survey at a single radiology residency training program. *J Am College Radiol.* 2018;15(12):1753–1757. doi:10.1016/j.jacr.2017.12.021

28. Jammal AA, Thompson AC, Mariottoni EB, et al. Human versus machine: comparing a deep learning algorithm to human gradings for detecting glaucoma on fundus photographs. *Am J Ophthalmol.* 2020;211:123–131. doi:10.1016/j.ajo.2019.11.006
29. Alexiadis A. Deep multiphysics: coupling discrete multiphysics with machine learning to attain self-learning in-silico models replicating human physiology. *Artif Intell Med.* 2019;98:27–34. doi:10.1016/j.artmed.2019.06.005
30. Song HX, Sun Z, Hao Y, et al. Machine learning-assisted prediction and optimization of electrocatalytic activity. *J Mater Sci Technol.* 2026;245:17–32. doi:10.1016/j.jmst.2025.04.050
31. Zou LX, Wang X, Hou Z-L, et al. Machine learning algorithms for diabetic kidney disease risk predictive model of Chinese patients with type 2 diabetes mellitus. *Renal Failure.* 2025;47(1). doi:10.1080/0886022X.2025.2486558.
32. Tsang KCH, Pinnock H, Wilson AM, et al. Application of machine learning algorithms for asthma management with mHealth: a clinical review. *J Asthma Allergy.* 2022;15:855–73.
33. Goo HW, Park SJ, Yoo SJ. Advanced medical use of three-dimensional imaging in congenital heart disease: augmented reality, mixed reality, virtual reality, and three-dimensional printing. *Korean J Radiol.* 2020;21(2):133–145. doi:10.3348/kjr.2019.0625
34. Moro C, Birt J, Stromberga Z, et al. Virtual and augmented reality enhancements to medical and science student physiology and anatomy test performance: a systematic review and meta-analysis. *Anatom Sci Educ.* 2021;14(3):368–376. doi:10.1002/ase.2049
35. Dhar P, Rocks T, Samarasinghe RM, et al. Augmented reality in medical education: students' experiences and learning outcomes. *Medical Education Online.* 2021;26(1). doi:10.1080/10872981.2021.1953953.
36. Mondal H, Mondal S. Adopting augmented reality and virtual reality in medical education in resource-limited settings: constraints and the way forward. *Adv Physiol Educ.* 2025;49(2):503–507. doi:10.1152/advan.00027.2025
37. Zayet TMA, Ismail MA, Almadi SH, et al. What is needed to build a personalized recommender system for K-12 students' E-learning? Recommendations for future systems and a conceptual framework. *Educ Inform Technol.* 2022;28(6):7487–508.
38. Ahmed ST, Mahesh TR, Srividhya E, et al. Towards blockchain based federated learning in categorizing healthcare monitoring devices on artificial intelligence of medical things investigative framework. *BMC Med Imaging.* 2024;24(1). doi:10.1186/s12880-024-01279-4.
39. Komolafe OO, Mustofa J, Daley MJ, et al. Current applications and outcomes of AI-driven adaptive learning systems in physical rehabilitation science education: a scoping review protocol. *PLoS One.* 2025;20(6):e0325649. doi:10.1371/journal.pone.0325649
40. Xu XW. AI optimization algorithms enhance higher education management and personalized teaching through empirical analysis. *Sci Rep.* 2025;15(1):10157.
41. Li A, Wang YX, Chen HX. AI driven cardiovascular risk prediction using NLP and large language models for personalized medicine in athletes. *Stas Technol.* 2025;32:100286.
42. Koçak M, Oguz AK, Akçali Z. The role of artificial intelligence in medical education: an evaluation of large language models (LLMs) on the Turkish medical specialty training entrance exam. *Bmc Med Educ.* 2025;25(1). doi:10.1186/s12909-025-07148-0
43. Li Z, Fenghe L, Xuehu W, et al. Ethical considerations and fundamental principles of large language models in medical education: viewpoint. *J Med Internet Res.* 2024;26:e60083.
44. Alonso A, Siracuse JJ. Protecting patient safety and privacy in the era of artificial intelligence. *Semin Vasc Surg.* 2023;36(3):426–429. doi:10.1053/j.semvascsurg.2023.06.002
45. Ruotsalainen PS, Blobel B, Seppälä A, et al. Trust information-based privacy architecture for ubiquitous health. *Jmir mHealth and uHealth.* 2013;1(2):e23. doi:10.2196/mhealth.2731
46. Sridharan K, Sequeira RP. Artificial intelligence and medical education: application in classroom instruction and student assessment using a pharmacology & therapeutics case study. *Bmc Medical Education.* 2024;24(1). doi:10.1186/s12909-024-05365-7
47. Lu L, Zhong Y, Luo S, et al. Dilemmas and prospects of artificial intelligence technology in the data management of medical informatization in China: a new perspective on SPRAY-type AI applications. *Health Informatics J.* 2024;30(2). doi:10.1177/14604582241262961.
48. Sivarajah RT, Curci NE, Johnson EM, et al. A review of innovative teaching methods. *Acad Radiol.* 2019;26(1):101–113. doi:10.1016/j.acra.2018.03.025
49. Armstrong P, Elliott T, Ronald J, et al. Comparison of traditional and interactive teaching methods in a UK emergency department. *Eur J Emerg Med.* 2009;16(6):327–329. doi:10.1097/MEJ.0b013e32832b6375
50. Pan DP, Guo Y, Fan Y, et al. Development and application of traditional chinese medicine using ai machine learning and deep learning strategies. *Ame J Chin Med.* 2024;52(03):605–623. doi:10.1142/S0192415X24500265
51. Windermere SA, Shah S, Hey G, et al. Applications of artificial intelligence in neurosurgery for improving outcomes through diagnostics, predictive tools, and resident education. *World Neurosurg.* 2025;197.
52. Lin S, Duong A, Nguyen C, et al. Five years' experience with a medical scribe fellowship: shaping future health professions students while addressing provider burnout. *Acad Med.* 2021;96(5):671–679. doi:10.1097/ACM.0000000000003757
53. Khan HU, Ali Y, Khan F, et al. A comprehensive study on unraveling the advances of immersive technologies (VR/AR/MR/XR) in the healthcare sector during the COVID-19. *Challeng Solut Heliyon.* 2024;10(15).
54. Triola MM, Rodman A. Integrating generative artificial intelligence into medical education: curriculum, policy, and governance strategies. *Acad Med.* 2025;100(4):413–418. doi:10.1097/ACM.0000000000005963
55. Wolf J, Rasmussen DK, Sun YJ, et al. Liquid-biopsy proteomics combined with AI identifies cellular drivers of eye aging and disease. *Cell.* 2023;186(22):4868. doi:10.1016/j.cell.2023.09.012
56. Anvar SY, Tucker A, Vinciotti V, et al. Interspecies translation of disease networks increases robustness and predictive accuracy. *PLOS Computat Biol.* 2011;7(11). doi:10.1371/annotation/fe0b4192-6427-4fb3-b347-c66651adf855.
57. Sun MJ, Liu M, Zhang X, et al. First identification of a biovar 4 strain from yak in Tibet, China. *Vet Microbiol.* 2020;247:108751.
58. Luo D, Chen X, Wang M, et al. Analyzing spatial delays of tuberculosis from surveillance and awareness surveys in Eastern China. *Sci Rep.* 2024;14(1).
59. Huang G, Wei X, Tang H, et al. A systematic review and meta-analysis of diagnostic performance and physicians' perceptions of AI-assisted CT diagnostic technology for the classification of pulmonary nodules. *J Thoracic Dis.* 2021;13(8):4797. doi:10.21037/jtd-21-810
60. Oliveira PBD, Cunha JB. Blending artificial intelligence into PID controller design: a. *Biomed Enginee Exper Ifac Papersonline.* 2016;49(6):366–371. doi:10.1016/j.ifacol.2016.07.205

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