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Integrating AI in medical education: a comprehensive study of medical students' attitudes, concerns, and behavioral intentions

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Abstract

Background To analyze medical students' perceptions, trust, and attitudes toward artificial intelligence (AI) in medical education, and explore their willingness to integrate AI in learning and teaching practices.

Methods This cross-sectional study was performed with undergraduate and postgraduate medical students from two medical universities in Beijing. Data were collected between October and early November 2024 via a self-designed questionnaire that covered seven main domains: Awareness of AI, Expectations and concerns about AI, Importance of AI in education, Potential challenges and risks of AI in education and learning, The role and potential of AI in education, Perceptions of generative AI, and Behavioral intentions and plans for AI use in medical education.

Results A total of 586 students participated in the survey, 553 valid responses were collected, giving an effective response rate of 94.4%. The majority of participants reported familiarity with AI concepts, whereas only 43.5% had an understanding of AI applications specific to medical education. Postgraduate students exhibited significantly higher levels of awareness of AI tools in medical contexts compared with undergraduate students ($p < 0.001$). Gender differences were also observed, with male students showing more enthusiasm and higher engagement with AI technologies than female students ($p < 0.001$). Female students expressed greater concerns regarding privacy, data security, and potential ethical issues related to AI in medical education than male students ($p < 0.05$). Male students or postgraduate students showed stronger behavioral intentions to integrate AI tools in their future learning and teaching practices.

Conclusions Medical students exhibit optimistic yet cautious attitudes toward the application of AI in medical education. They acknowledge the potential of AI to enhance educational efficiency, but remain mindful of the associated privacy and ethical risks. Strengthening AI education and training and balancing technological advancements with ethical considerations will be crucial in facilitating the deep integration of AI in medical education.

Trial registration Not clinical trial.

Keywords Artificial intelligence, Medical education, Attitudes, Concerns, Behavioral intentions

The rapid development of artificial intelligence (AI) is profoundly transforming various sectors of society, redefining educational models, and bringing unprecedented changes and possibilities to higher education [1, 2]. The application of AI in education is collectively referred to as AIEd (artificial intelligence in education), and it is widely used in areas such as knowledge management,

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enhancing teaching efficiency, and personalized learning [3–5]. AI could significantly increase students' engagement and participation in learning [6]. Many university students are leveraging AI tools to address everyday learning challenges, such as using large language models (like ChatGPT, DeepSeek, etc.) for knowledge question-and-answer scenarios, language translation, and writing assistance [7, 8]. The role of AI in education goes beyond providing information, as it can improve teacher-student relationships by acting as a tutor and helping students grasp complex knowledge [9]. However, the adoption of AIEd varies across disciplines, with notable differences in the level of technological training and acceptance between science, technology, engineering, and mathematics (STEM) and non-STEM fields [10]. STEM students are more likely to embrace AIEd because of their systematic exposure to AI technologies, whereas non-STEM students may lack a foundational understanding of AI and tend to have lower recognition and use of AI tools.

The medical education is inherently a long-term process; training qualified physicians from students in China usually takes about a decade, including both undergraduate education and postgraduate programs. Throughout, students are required to master a range of knowledge, from anatomy and pathology to clinical courses. Under traditional teaching methods, students primarily rely on textbooks, lectures, and clinical practice to acquire knowledge. Recently, the rapid development of AI has significantly improved the learning experiences. For example, AI-based tools, such as intelligent virtual patient systems, advanced teaching platforms, and generative AI-based question-and-answer systems are progressively emerging in medical education, presenting opportunities to improve teaching efficacy and educational quality [11–13]. Moreover, AI tools assist instructors in optimizing the teaching process and provide personalized learning support and clinical practice functionality for students [14, 15]. However, the reliability of AI-generated outcomes remains highly controversial. This uncertainty has heightened concerns among some medical educators and students regarding AI technologies. These concerns could influence students' perceptions, expectations, and attitudes toward AI, thereby impacting teaching effectiveness. According to the Theory of Planned Behavior, individuals' attitudes play a key role in shaping individuals' future intentions and practices [16]. Comprehending medical students' attitudes toward AI is essential for shaping their future behavior, and evaluating their acceptance and potential application of AIEd is crucial to understanding the advantages and challenges of AI in medical education and promoting its effective integration. However, previous research has not provided a systematic and comprehensive analysis of AI awareness across different stages of medical education.

To bridge this gap, this study systematically examines the perceptions, trust, and attitudes toward AI among more than 500 undergraduate and postgraduate students from two medical schools in Beijing, utilizing a questionnaire-based survey. It explores medical students' perceptions of the opportunities and challenges presented by AI in medical education, especially their willingness to accept AI technologies. The results will guide the creation of specialised AI curriculum and training projects. This research could assist educators and policymakers in addressing student concerns, enhancing AI integration in medical education, and promoting responsible adoption of AI in clinical practice.

Methods

Participants

This cross-sectional study used convenience sampling to survey students enrolled at two medical universities in Beijing. Data collection was concentrated in October and early November 2024. The questionnaire targeted both undergraduate and postgraduate students and was distributed during class sessions, before being administered in an online format. In total, 586 students participated in this survey; however, 33 students returned incomplete questionnaires and were excluded from the analysis.

Questionnaire design

The questionnaire was developed based on previous literature and organized into seven sections. These sections including: 1) awareness of AI, 2) expectations and concerns about AI, 3)the importance of AI in education, 4) potential challenges and risks of AI in education and learning, 5) the role and potential of AI in education, 6) perceptions of generative AI, and 7) behavioral intentions and plans for AI use in medical education. Pilot studies were conducted before formal data collection to ensure the relevance and clarity of the questionnaire items, and the questionnaire was revised based on the feedback. The final version of the questionnaire comprised 52 items. Responses were measured on a 5-point Likert scale from "Strongly agree" to "Strongly disagree." Participation was completely voluntary, and all responses were collected anonymously.

Statistical analyses

The data analyses were performed using SPSS version 22.0. Categorical variables were reported as percentages, and continuous variable as mean and standard deviation (SD). T- tests were used to compare differences in continuous variables between groups, with a p-value < 0.05 indicative of a statistically significant difference.

Reliability analysis of the scales was performed using Cronbach's alpha coefficient, and validity analysis was conducted using exploratory factor analysis.

Results

A total of 553 valid responses were received in this study, comprising 289 male and 264 female participants. Among them, 235 (42.5%) were undergraduate students and 318 (57.5%) were postgraduate students. The age distribution analysis revealed that 291 (52.62%) were between 18 and 25 years old, 251 (45.39%) were aged 26 to 35 years, and 11 were 36 years or older. The demographic characteristics of the participants are presented in Table 1. Among the undergraduate students, 116 were male (49.4%) and 119 were female (50.6%). The postgraduate students comprised master's students ($n=166$, 52.2%), doctoral students ($n=117$, 36.7%), and part-time postgraduate students ($n=35$, 11.1%). Their areas of specialization included surgery ($n=109$), internal medicine ($n=64$), and other disciplines, such as obstetrics and gynecology, pediatrics, and medical imaging ($n=145$).

Table 1 Demographic information

Variables		N	Percentage (%)
Gender	Male	289	52.26
	Female	264	47.74
Age, years	18–25	291	52.62
	26–35	251	45.39
	≥ 36	11	1.63
Academic level	Undergraduate	235	42.50
	Postgraduate	318	57.50

As illustrated in Fig. 1, the majority of respondents (73.14%) demonstrated moderate to strong understanding of AI and related technologies, 43.22% of respondents reporting a neutral stance and 36.98% expressing agreement or strong agreement about their familiarity with AI concepts such as machine learning and deep learning. However, only a small proportion (5.06%) strongly agreed that they fully understood the underlying principles of AI. When asked about AI's role in medical education, a significant portion (60.21%) expressed interest in AI-based applications, such as virtual patient systems and intelligent teaching platforms. Conversely, privacy concerns were prevalent, with 78.3% acknowledging worries about AI-related privacy issues, and 84.81% expressing concerns regarding the accuracy of AI-generated

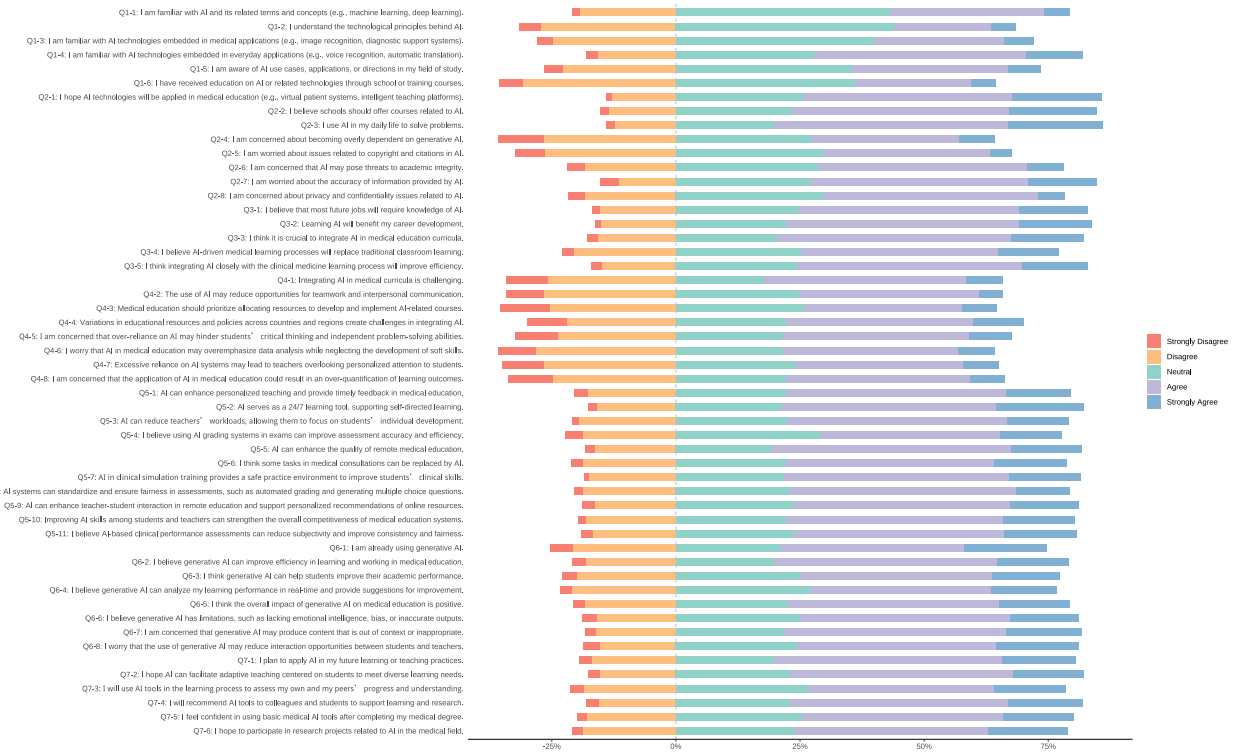

Fig. 1 Medical Students' Perceptions, Attitudes, and Behavioral Intentions Toward AI in Medical Education. This figure presents the medical students' responses to questionnaire items assessing their awareness, expectations, concerns, attitudes, and behavioral intentions regarding AI in medical education. The questionnaire items are shown on the left, and corresponding bar charts of answers are illustrated on the right

results. On AI's potential to transform education, 61.72% of respondents recognized the positive impact AI could have on personalized learning and timely feedback, with 44.30% agreeing and 13.02% strongly agreeing. However, 40.69% acknowledged the challenges in integrating AI into medical curricula. Despite these concerns, a large proportion (45.75%) expressed intent to incorporate AI tools in future learning or teaching practices. Additionally, 43.94% indicated they would recommend AI tools to colleagues and students, while 40.51% felt confident in using basic medical AI tools after completing their medical degree.

As presented in Table 2, male participants reported higher mean scores for basic awareness of AI, expectations for AI, importance of AI in careers and education, the role and potential of AI in education, perceptions of generative AI, and behavioral intentions and plans than females. Conversely, females showed higher mean scores for concerns about AI and potential challenges and risks of AI in education. These findings suggested that males tended to have more optimistic views of AI, whereas females were more cautious, particularly regarding risks and challenges in education. Significant differences were also observed between undergraduate and postgraduate students in certain aspects of their AI-related perceptions (Table 3). Postgraduate students scored significantly higher than undergraduates in awareness of AI, suggesting that postgraduate students had a better understanding of AI-related concepts and applications. Postgraduate students also scored slightly higher than undergraduates for concerns about AI, indicating they had a greater apprehension about AI-related risks. However, no significant differences were found between the two groups in expectations about AI, importance of AI in education, potential challenges and risks of AI in education and learning, the role and potential of AI in education,

Table 2 Gender differences across all dimensions related to artificial intelligence (AI)

	Male ($n=289$) mean ± SD	Female($n=264$) mean ± SD	t	*p*	95%CI
Awareness of AI	3.29 ± 0.78	2.93 ± 0.74	5.54	0.000**	0.231, 0.485
Expectations about AI	3.76 ± 0.89	3.52 ± 0.77	3.53	0.000**	0.111, 0.388
Concerns about AI	3.15 ± 0.84	3.32 ± 0.81	-2.468	0.014*	-0.312, -0.036
Importance of AI in education	3.68 ± 0.82	3.34 ± 0.74	5.160	0.000**	0.212, 0.473
Potential challenges and risks of AI in education and learning	2.94 ± 0.99	3.25 ± 0.78	-4.141	0.000**	-0.461, -0.164
Role and potential of AI in education	3.66 ± 0.79	3.32 ± 0.71	5.272	0.000**	0.212,0.463
Perception of generative	3.62 ± 0.84	3.27 ± 0.79	4.97	0.000**	0.209, 0.483
AI Behavioral intentions and plans in AI use for medical education	3.65 ± 0.87	3.32 ± 0.74	4.761	0.000**	0.191, 0.459

SD standard deviation

* $p<0.05$

** $p<0.01$

Table 3 Differences across all dimensions related to artificial intelligence (AI) by academic level

	Undergraduate mean ± SD	Postgraduate mean ± SD	t	*p*	95%CI
Awareness of AI	2.86 ± 0.78	3.31 ± 0.72	6.98	0.00**	0.321, 0.577
Expectations about AI	3.67 ± 0.84	3.62 ± 0.85	−0.67	0.50	-0.191, 0.093
Concerns about AI	3.14 ± 0.90	3.29 ± 0.77	2.08	0.04*	0.008, 0.296
Importance of AI in education	3.48 ± 0.81	3.54 ± 0.80	0.93	0.35	-0.072, 0.200
Potential challenges and risks of AI in education and learning	3.13 ± 0.91	3.06 ± 0.91	−0.94	0.35	-0.227, 0.081
Role and potential of AI in education	3.48 ± 0.74	3.50 ± 0.80	0.36	0.72	-0.106, 0.153
Perception of generative AI	3.45 ± 0.78	3.47 ± 0.86	0.25	0.81	-0.129, 0.155
Behavioral intentions and plans in AI use for medical education	3.49 ± 0.84	3.50 ± 0.81	0.15	0.88	-0.129, 0.151

SD standard deviation

* $p<0.05$

** $p<0.01$

perception of generative AI, or behavioral intentions and plans in AI use ($p > 0.05$). Additional results can be found in Supplementary Materials.

Discussion

The application of AI technologies in higher education is receiving widespread attention [3, 5]. As core participants in education, medical students' perceptions and attitudes toward AI play a crucial role in its promotion. This study findings indicate that while students acknowledge the potential advantages of AI in medical education, they are cautious of its limitations, particularly in relation to privacy, ethical concerns, and the accuracy of content produced by AI. The academic level affects students' awareness of and concerns about artificial intelligence, with postgraduate students exhibiting a higher degree of familiarity with AI applications. This may be because postgraduate students are more accustomed to using AI tools for professional tasks, such as automated data analysis and intelligent diagnostic support. This aligns with prior studies demonstrating that engagement with particular AI tools and involvement in research enhance graduate students' AI literacy [17]. However, although postgraduate students are more familiar with AI, they also have greater concerns, possibly because they are increasingly involved in research and clinical work, both of which require strict data protection. In addition to differences in academic level, gender also played a significant role in shaping perceptions of AI. Male students showed a greater interest in AI and reported higher self-perceived knowledge levels, especially in technical applications. In contrast, female students adopted a more cautious approach, expressing stronger concerns about the ethical implications of AI, including potential biases, its impact on human interactions, and data security [18].

AI technologies offer significant advantages in medical education by enabling personalized instruction, adapting learning materials to individual student needs, and enhancing remote education through interactive and intelligent learning systems, and these capabilities improve learning efficiency and overall educational quality [19]. Both undergraduate and postgraduate students recognized the importance of learning AI technologies for their career development and hoped to see them incorporated in medical curricula. Moreover, participating students planned to actively apply AI technologies in their future learning and teaching and were willing to recommend related tools to their peers. However, medical students also specifically expressed apprehensions about over-reliance on AI, the accuracy of AI-generated information, and its potential impact on independent learning.

Generative AI models have recently garnered attention for their capacity to assess intricate medical and clinical information, rendering them important assets for education and research [20–24]. These technologies can enhance learning efficiency through individualized training, facilitation of knowledge synthesis, and augmentation of research output. However, despite these advantages, concerns persist regarding its reliability, particularly in ensuring factual correctness in medical contexts. AI-generated content could exhibit mistakes, nonsensical elements, insufficient sourcing, or references to non-existent sources [25, 26]. Many AIEd models are developed using relatively limited datasets, some of which may contain sensitive patient information. As a result, AI-generated outputs can be biased due to inadequate training data and other influencing factors [26]. Additionally, researchers have highlighted ethical and academic integrity issues, including authorship disputes, copyright, authenticity, plagiarism, and the potential misuse of AI-generated content in assessments [20, 22]. Therefore, integrating AI into medical education should focus not only on developing students' technical skills to use AI effectively but also on enhancing their ability to critically evaluate AI-generated content. To ensure reliability, AI models for medical education should be trained using high-quality, verified teaching materials and data sources that are accurate, evidence-based, and free from biases. Additionally, strict restrictions must be established on the autonomous reasoning and divergence of AI models to avoid the production of contextually irrelevant or unverifiable content. Incorporating AI bias training into medical curricula is essential for educators, as it equips students to critically assess AI-generated data and identify potential biases. Thus, A principle-based approach to teaching AI ethics in medical education is recommended, building on established medical ethics principles and incorporating public health ethics to address these challenges comprehensively [27]. In addition, to alleviate concerns regarding information leakage in specific regions or institutions, lightweight multimodal large models may be implemented locally with restricted access protocols to ensure privacy and security. These measures will mitigate ethical risks and promote the responsible use of AI in medical education.

The outcomes of our study support the Theory of Planned Behavior. Specifically, students' views on AI were shaped by perceived advantages like improved learning efficiency and tailored instruction, along with possible drawbacks such as data privacy concerns and ethical risks. These attitudes played a key role in influencing their likelihood of adopting AI technologies. Furthermore, the psychological construct of subjective norms, encompassing faculty attitudes and peer influence,

emerged as a significant determinant in students' acceptance of AI. While many participants expressed enthusiasm for integrating AI into medical education, a lack of practical experience contributed to their hesitancy in actual application. Addressing these gaps through targeted AI training and structured curriculum integration could enhance students' confidence and facilitate the responsible adoption of AI technologies. To improve students' mastery of AI tools, medical education institutions should provide more practice-oriented teaching formats, such as workshops based on real-life cases and online simulation courses. Through these practical components, students can familiarize themselves with the actual application of AI technology in a safe, simulated environment. In addition, promoting interdisciplinary collaboration where AI technologies are integrated with practical medical problems (e.g., diagnostic support, image analysis) will enhance students' confidence in the technology and improve their ability to solve complex problems [28, 29]. Furthermore, gradually introducing AI certification and evaluation standards in medical education will help to clarify the application norms and practical value of the technology, thereby increasing AI's credibility and students' adoption rates [30, 31]. In addition, policymakers should regulate the application of AI technologies in educational settings and ensure they serve as beneficial aids to classroom teaching and practical training rather than complete replacements. Educational institutions need to strike a balance between the proliferation of technology and ethical standards [32]. On one hand, the potential of AI in advancing educational modernization should be fully leveraged. On the other, strengthening ethics education and risk management can ensure the safety and effectiveness of technological applications, thereby supporting the sustainable development of medical education.

Additionally, the global integration of AI-driven medical education holds significant long-term implications for the future of medical training and practice. However, substantial disparities exist in the adoption and proliferation of AI technologies across different countries and regions [33]. In particular, students in resource-limited developing countries may struggle to access comprehensive AI education because of inadequate educational infrastructure and policy support. A multinational study revealed that over 92% of medical students had not received formal AI education, and approximately 87% only had a basic understanding of AI [34]. A study conducted in China found about 34.5% of medical students had heard of and used large language models in relation to generative AI tools [17]. Although this study did not include geographic factors, we found that over two-thirds of participating students had some degree of understanding of the technical principles behind AI. To bridge the AIEd gap across different regions, global collaboration and resource-sharing initiatives are paramount. Additionally, by establishing open educational resources and course designs tailored to local needs, we can provide more equitable learning opportunities for students in underdeveloped regions, thus promoting the balanced development of AI education in the medical field globally.

In conclusion, students have optimistic yet cautious attitudes toward the use of AI in medical education. They are reasonably familiar with AI-related terms and concepts and recognize the potential advantages of AI in enhancing educational efficiency and optimizing teaching models, while remaining cautious about its limitations and risks (e.g., privacy concerns and ethical challenges). Strengthening AI education and training while balancing technological advancements with ethical considerations will be crucial to facilitate the deep integration of AI in medical education. This will expand the possibilities for the modernization of medical education and present an important opportunity to address the new challenges posed by the application of AI technologies.

This study has several limitations. First, the sample was drawn from Beijing and primarily consisted of medical students, factors such as regional differences or students' backgrounds (e.g. urban–rural disparities, family environments) might have influenced the results, potentially leading to bias. Second, as this study used a cross-sectional design with a relatively limited sample size, we could not clarify the dynamic long-term impacts of AI on medical education. Third, this survey's reliance on self-reported data may introduce biases, such as social desirability and recall bias, possibly affecting the accuracy of reported attitudes and experiences. Further research should address these limitations by expanding the sample size to include students from multiple regions and diverse backgrounds and incorporating longitudinal studies and intervention trials to assess the evolving impact of AI. Given that AI in medical education is still in its exploratory phases, further studies should focus on evaluating its effectiveness in achieving intended educational outcomes.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12909-025-07177-9.

Supplementary Material 1.

Supplementary Material 2.

Authors' contributions

Shuo Duan and Chunyu Liu were major contributors in writing the original manuscript and data analysis. Tianhua Rong, Yixin Zhao, and Shuo Duan conducted the questionnaire survey, data collection, and visualization. Baoge Liu

and Yixin Zhao were responsible for conceptualizing, supervising, and writing the review & editing. Shuo Duan and Chunyu Liu made equal contributions and are co-first authors. Baoge Liu and Yixin Zhao are co-corresponding authors. All authors read and approved the final manuscript.

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Data availability
The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by the Medical Ethics Committees of Capital Medical University and Peking University Health Science Center. All participants were informed that participation was voluntary, and written informed consent was obtained. Participant information and all data materials were anonymized and securely stored in a database. This study was conducted in accordance with the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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