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Application of artificial intelligence in medical education: A meta-ethnographic synthesis

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ABSTRACT

Background: With the advancement of Artificial Intelligence (AI), it has had a profound impact on medical education. Understanding the advantages and issues of AI in medical education, providing guidance for educators, and overcoming challenges in the implementation process is particularly important.

Objective: The objective of this study is to explore the current state of AI applications in medical education.

Methods: A systematic search was conducted across databases such as PsycINFO, CINAHL, Scopus, PubMed, and Web of Science to identify relevant studies. The Critical Appraisal Skills Programme (CASP) was employed for the quality assessment of these studies, followed by thematic synthesis to analyze the themes from the included research.

Results: Ultimately, 21 studies were identified, establishing four themes: (1) Shaping the Future: Current Trends in AI within Medical Education; (2) Advancing Medical Instruction: The Transformative Power of AI; (3) Navigating the Ethical Landscape of AI in Medical Education; (4) Fostering Synergy: Integrating Artificial Intelligence in Medical Curriculum.

Conclusion: Artificial intelligence's role in medical education, while not yet extensive, is impactful and promising. Despite challenges, including ethical concerns over privacy, responsibility, and humanistic care, future efforts should focus on integrating AI through targeted courses to improve educational quality.

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KEYWORDS
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Introduction

Artificial Intelligence (AI), a subset of computer science, emulates intelligent human actions and cognitive functions. Through techniques such as machine learning, natural language processing, and computer vision [1], AI empowers machines to undertake complex tasks such as learning, reasoning, perception, and problem-solving. With recent AI research progress, AI integration into medical education has grown, encompassing tools like GPT, virtual patients, and chatbots, broadening its educational role [2]. Concurrently, a variety of issues arise with artificial intelligence, such as its limitations, barriers to integration with medical education, and ethical concerns [3].

AI is revolutionizing medical education by innovating teaching and learning methods. Extensively researched across specialties like diagnostics, imaging, histopathology, cardiology, psychology, healthcare administration, and drug development [4]. It provides the design of personalized learning pathways, simulation of virtual patients, intelligent tutoring and assessment systems, and AI-driven clinical decision support tools [5,6]. Significantly, OpenAI's generative pre-trained transformer, ChatGPT, has swiftly amassed a million users in five days. Its capacity to produce human-like text and interactive dialogues offers detailed, pertinent information, boosting student engagement and results [7]. Virtual patient simulations facilitate risk-free clinical practice, enabling diagnostic and treatment planning through questioning and examinations. This approach enhances understanding of complex medical concepts and practical skills, thereby improving teaching efficiency and quality

Practice points

- Artificial intelligence is currently not widely applied in medical education, but it holds broad prospects.
- The powerful capabilities of artificial intelligence offer significant assistance in learning and clinical practice, enhancing the quality and efficiency of medical education and clinical work.
- Artificial intelligence exhibits certain shortcomings, particularly ethical concerns that have elicited widespread apprehension.
- Integrating artificial intelligence into the medical education curriculum may be one of the methods to foster the integration of the two domains.

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[8–10]. In the field of anatomy, AI can enhance the academic performance of medical learners in anatomy through increased interactive interventions[11]. AI can also assist educators in monitoring students' progress, refining educational materials, and enhancing clinical and interdisciplinary training to cultivate well-rounded medical practitioners [12].

AI in medical education, while transformative, raises ethical and transparency issues, with concerns over the opacity of its decision-making processes [13], which is detrimental to establishing trust between them. Humanistic care in medicine is vital as patients need dignity and respect beyond physical care. Evidence suggests AI technologies, like chatbots, can mitigate patients' negative psychological states through conversation [14], but this does not imply that artificial intelligence possesses empathy comparable to that of humans. However, there is ongoing controversy over whether AI can possess empathy that is comparable to human empathy. The accuracy of AI's output has yet to be fully affirmed, and the issue of accountability for errors during its use has not been conclusively determined [15]. AI's advanced capabilities have sparked fears among some medical professionals that it might replace their jobs, possibly causing complete displacement. This apprehension could affect their specialty choices, potentially impeding progress in medical field [16,17].

Despite growing research on AI in medical education, a meta-analysis is required to reveal AI's effects, highlighting its potential to improve educational experiences for instructors and students [18]. This study uses Meta-ethnographic synthesis to explore views of stakeholders, identify AI adoption facilitators, and consider its limitations and ethics. The results aim to inform AI's role and application in medical education.

Objective

This study aims to synthesize current qualitative research to explore the current state of artificial intelligence in medical education.

Methods

Search strategy

The literature search was executed across databases including PsycINFO, CINAHL, Scopus, PubMed, and Web of Science, covering records from the beginning of each database's history up to and including February 2024. Studies had to use at least one key word in the title, keywords, and/or abstract for each of the following aspects: (1) Key word for Artificial Intelligence: 'Intelligence, Artificial' or 'Computer Reasoning' or 'Reasoning, Computer' or 'AI (Artificial Intelligence)' or 'Machine Intelligence' or 'Intelligence, Machine' or 'Computational Intelligence' or 'Intelligence, Computational' or 'Computer Vision Systems.' (2) Key word for medical education: 'Education, Medical' or 'Medical Education' or 'Nursing education' or 'Teaching' or 'Learning.' For this meta-analytic examination, we began by integrating terms with equivalent meanings using the Boolean 'OR' operator. Subsequently, these concepts were unified using the Boolean 'AND' operator.

Inclusion criteria

All literature were assessed independently by a minimum of two reviewers. Inclusion of documents was contingent upon fulfillment of the subsequent criteria.

Firstly, the article must assess the current state of the use of artificial intelligence in medical education. Artificial intelligence may encompass specific applications such as large language models (e.g. ChatGPT), chatbots, virtual patient systems, and so on. Studies focusing on evaluating the use of artificial intelligence in clinical settings or other healthcare facilities are excluded, as they deviate from the field of medical education. Participants may include students in the medical field (including undergraduates and postgraduates), teachers engaged in the medical profession, and other workers in medical education (mentors, laboratory researchers, and educational consultants, etc.). Long-term hospital staff are excluded as they may have limited understanding of school education.

Second, the studies under consideration must be original research employing qualitative methods or original mixed-methods research; mixed-methods studies lacking qualitative components are excluded. Although review articles encompass conclusions drawn by influential scholars, they are not considered in this study due to the research design of the present article.

Third, articles must be published in peer-reviewed journals that disseminate content in English. Conference papers and academic theses are excluded from consideration.

Quality appraisal of included studies

The quality assessment was conducted using the Critical Appraisal Skills Programme (CASP). The assessment process was conducted independently by two researchers using a checklist that included ten items, each item was coded as Y (yes) = 1 point, N (no) = 0 points, or CT (Cannot tell) = 0.5 points [19], with a total score of 10 points. Discrepancies were resolved through discussion, with the involvement of a third party as needed. Ultimately, the included literature was categorized into three groups: high quality (9-10 points), moderate quality (6-8.5 points), and low quality (0-5.5 points) [20]. Articles categorized into high and moderate quality groups were included in the meta-analysis, while the low-quality group was excluded.

Data abstraction

Information from each study was collected individually by two researchers, with any discrepancies resolved through discussion. Specifically, the following details were extracted: author, publication year, country, purpose of the study, research methodology, data collection methods and timing, data source environment, and the data analysis methods used. The identity or occupation of the participants (such as students or teachers) was also noted. The primary findings of the study are derived from the themes of the included articles, which pertain to the perceptions of medical students, educators, and other medical education professionals regarding the application of artificial intelligence in medical education. If the articles do not present their findings in a thematic format, the results of the articles are

thematically summarized. The extracted data also includes quotations from participants regarding their evaluations of artificial intelligence. These quotations will be presented as supplementary to the thematic descriptive perspectives in the results section.

Data synthesis

The raw data extracted from the previous step was analyzed using the steps of argumentative meta-ethnography synthesis as described by Noblit and Hare [23] , to determine the attitudes of medical students, teachers, and healthcare workers towards artificial intelligence in medical education. The first-order structure is the 'everyday understanding of research participants,' which includes the attitudes of medical students, teachers, and other medical education professionals towards the application of artificial intelligence in medical education. The second-order structure is the 'original author's structural understanding of the research participants,' that is, the original author's interpretation of the information obtained in the first stage. Our understanding of the second-order structure is referred to as the third-order structure [21]. The first-order, second-order, and third-order structures are used to synthesize arguments, providing new insights into the perspectives of students, teachers, and medical educators [22]. The process of data synthesis was conducted independently by two authors, with disagreements resolved through dialogue, and a third party was invited to discuss when necessary to reach a consensus. All authors involved in the data synthesis were proficient in the use of large language models and other artificial intelligence technologies.

Data analysis encompasses four steps: identifying relevant data; recognizing and associating structures; reinterpreting structures; and synthesizing arguments [22]. In the first phase of data analysis, the 21 included articles were assigned to two authors. Each independently and thoroughly read every line of the extracted text to fully and completely understand each study and identify meaningful sections about the primary outcomes within the text. Repeated readings enabled the identification of recurring concepts in each article. In the second phase of data analysis, it was necessary to determine meaningful structures and consider the relationships between structures from different original studies. We created a shared Excel spreadsheet accessible to both authors, listing 'key metaphors, phrases, ideas, and/or concepts' from each narrative for further analysis [23]. The basic characteristics of the included studies (country, participants, and research methods, etc.) were also entered into Excel to help us understand the complex relationships between different studies from various perspectives and cultural backgrounds [24]. In the third phase of data analysis, all authors associated and reinterpreted the concepts or codes and their interactions from each study during internal meetings, forming new structures. These new structures are our interpretations of the data, known as third-order structures. We present the third-order structures in the form of themes and subthemes. In the final phase of data analysis, all authors discussed the information on the basic research characteristics of the included studies, second-order structures, identified structures, and third-order structures during internal meetings to synthesize arguments.

Results

Study selection and characteristics

A total of 2,067 literature pieces were retrieved and independently evaluated by at least two authors. After removing duplicate sources, 1,367 studies remained. The titles and abstracts of these studies were reviewed next, leading to the identification and assessment of the full texts of potentially relevant records. At the full-text review stage, 52 articles were excluded for specific reasons outlined in the PRISMA flow diagram (Figure 1). These reasons include the lack of utilization of artificial intelligence technology, research not being targeted at the field of medical education, and the studies not being qualitative research. Ultimately, 21 articles were included in this study.

Table 1 presents the descriptive details of the included studies, with these preliminary data providing context for further analysis. In the reviewed literature, the publication years spanned from 2021 to 2024, involving a total of 13 countries: United States ($n = 4$), Australia ($n = 2$), China ($n = 3$), England ($n = 2$), Germany ($n = 2$), Canada ($n = 1$), Cyprus ($n = 1$), Japan ($n = 1$), Kazakhstan ($n = 1$), Pakistan ($n = 1$), Palestine ($n = 1$), Portugal ($n = 1$) and Türkiye ($n = 1$). Nine studies employed mixed-methods research approaches, while eleven utilized qualitative research methods, with semi-structured interviews being the most common data collection method ($n = 8$), followed by other methods such as online surveys and focus groups. The majority of the literature utilized content analysis ($n = 6$) or thematic analysis ($n = 9$) for data analysis, with research subjects including medical students, educators, and clinical practitioners. The assessment results of the included literature are presented in Table 2. The results indicate that these articles are of high quality.

Themes and subthemes

Table 3 presents an overview of the themes and subthemes. Twenty-one encompassing studies were interpreted and analyzed, yielding primary themes and 14 associated subthemes, which collectively address various facets of the application of artificial intelligence in medical education: (1) Shaping the Future: Current Trends in AI within Medical Education; (2) Advancing Medical Instruction: The Transformative Power of AI; (3) Navigating the Ethical Landscape of AI in Medical Education; (4) Fostering Synergy: Integrating Artificial Intelligence in Medical Curriculum.

Shaping the future: Current trends in AI within medical education

The gap in artificial intelligence education

The current state of AI integration in medical education reveals that students perceive AI interactions as rare in their curriculum. As a novel technology, both educators and students possess limited awareness of AI's current capabilities in this domain [25]. They lack formal educational opportunities concerning artificial intelligence, with

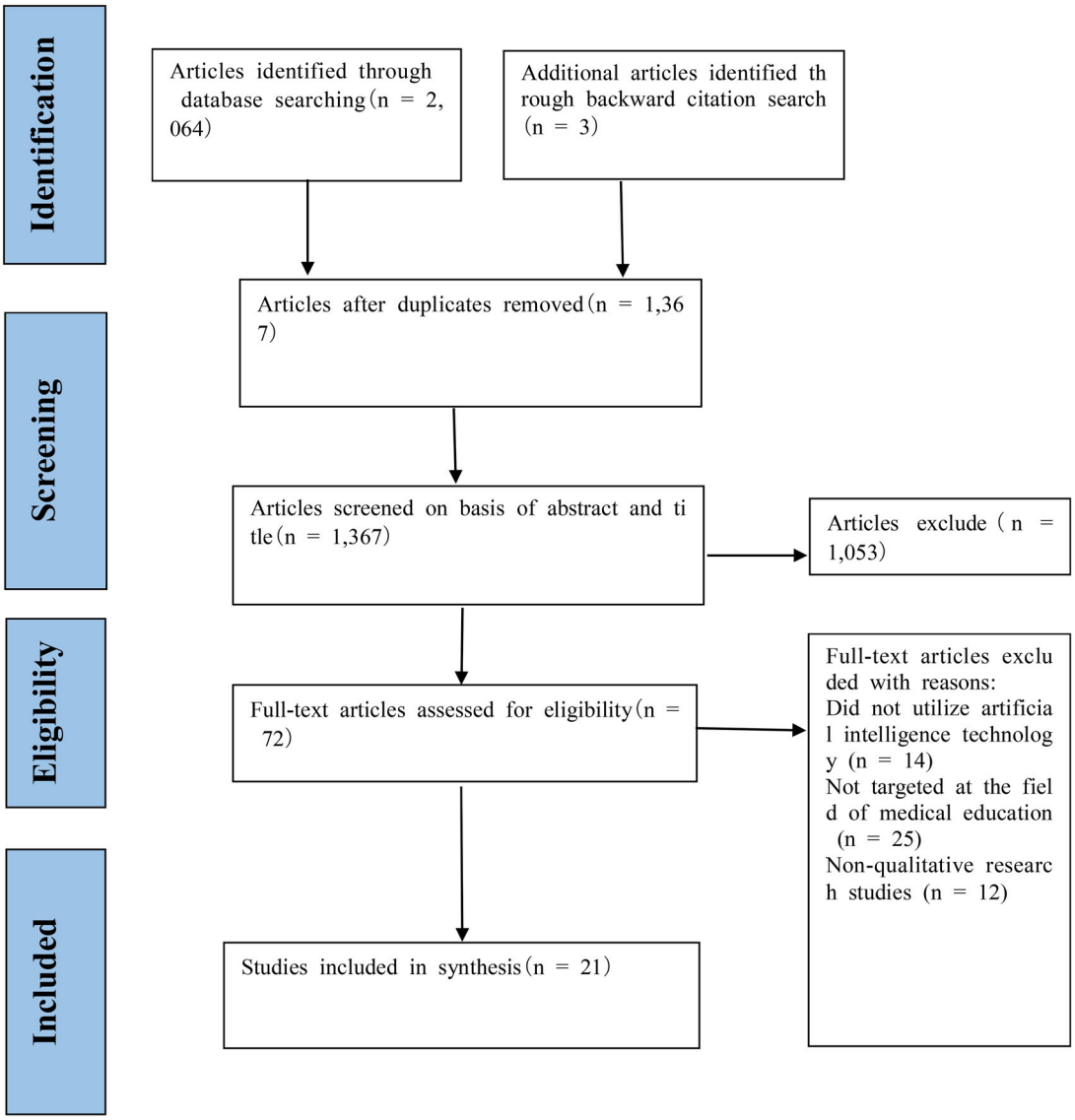

Figure 1. Flowchart of the review screening process.

current learning opportunities being informal or offered as elective courses, thus exceeding the boundaries of the standard curriculum [26–28].

> I did not get any opportunity during my undergraduate studies related to the use of AI technologies in medicine. Also, the study plan does not include courses related to AI. So my knowledge is very limited in this regard. I wish there was a course on AI in medical fields that would provide us with general information about AI, machine language, and algorithms. I am completely disappointed when I compare myself to students at international universities who have had the opportunity to interact with this topic [27].

Actively embracing

Medical students' attitudes towards artificial intelligence. Although artificial intelligence is not yet widely implemented in medical education, medical students exhibit a positive attitude towards its application, recognizing the significance of AI in their field. They have expressed an intention to incorporate artificial intelligence into their future study curriculum [9,26–30].

> [learning about AI] is important, because I think that it's going to be a reality in how a physician practices medicine and should be something we should learn [26].

Relative prioritization

Medical students recognize AI's role in med ed but don't see it as central to teaching methods. They prefer focusing on professional courses over AI due to limited study time. As grasping AI requires a strong background in math, programming, and CS, which is time-consuming, they're cautious about integrating AI into the curriculum [26,27].

> I think it is not necessary for medical curricula and study plans to contain courses related to AI because this is one of the tasks of the specialist or expert in the field of AI, machine language, and algorithms. Learning and mastering AI requires great effort and a long time, and this would negatively affect learning the medical skills that I have to master as a doctor [27].

Advancing medical instruction: The transformative power of AI

Enhancing medical education interaction and innovation

AI's benefits in medical education are clear; it streamlines learning and boosts efficiency [9]. It enhances interactivity, offering intelligent feedback and assessments [31]. As a virtual assistant, AI aids in human-computer interactions and understanding complex diagrams, facilitating knowledge

Table 1. Characteristic information of the included studies.

Author, Year	Country	Aim of the study	Methodology	Data collection methods; Setting; Data analysis	Participants and setting	Findings
Abid A [30]	United States	Assess the impact of a project-based curriculum, utilizing superior online resources, on self-reported AI and ML proficiency	Mixed method	Face-to-face semi-structured interviews Time: October 2021 Setting: University School of Medicine Data analysis: Descriptive manner	19 medical students Emory	Six themes (1) theoretical foundations (2) technical classifications (3) practical applications (4) limitations (5) ethical issues (6) specific applications and challenges in the field of medicine of machine learning
Araujo SM [9]	Portugal	Assess student views on ChatGPT in education and suggest faculty integration strategies in medical informatics for improved learning	Mixed method	Online survey Time: not reported Setting: Medicine of the University of Porto Data analysis: Thematic analysis	25 students	Four themes (1) AI response utilization (2) AI attitudes (3) AI as academic support views (4) Future AI use attitudes
Arruzza E [42]	Australia	Explore the perceptions of a sample of Australian radiography students regarding AI within the context of medical imaging	Qualitative	Online survey Time: September 2023 Setting: University of South Australia Thematic analysis	25 radiography students Setting:	Three themes (1) AI in medical imaging opinions (2) patient care quality concerns (3) job security and AI's impact on professional development
Balay-odao EM [32]	Kazakhstan	Assess student perceptions on AI integration in health education and care	Qualitative	Online survey Time: March 30-May 5, 2023 Setting: Nazarbayev University, School of Medicine Data analysis: Thematic analysis	33 health professions students	Four themes (1) interactive learning enhancement (2) AI diagnostic tools in health education (3) AI preparation for future healthcare roles (4) AI integration challenges
Blease C [40]	United States	Examine AI/ML familiarity and exposure among postgraduate clinical psychology students	Mixed method	Online survey Time: April-June 2020 Setting: Faculty of Psychology, University of Basel, Switzerland Data analysis: Content analysis	37 clinical psychology students	Four themes (1) changes in the quality and understanding of psychotherapy care (2) impact on patient-therapist interactions (3) impact on the psychotherapy profession (4) data management and ethical issues
Chen YY [25]	China	Explore nursing students' needs and essential components of chatbot-based history-taking instruction program	Qualitative	Semi-structured interviews Time: April and May 2022 Setting: Not reported Data analysis: Colaizzi's phenomenological methodology	22 nursing students	Three themes (1) clinical history-taking limitations (2) perceptions of chatbot-assisted history-taking (3) necessity of chatbot-based history-taking education
Ejaz H [29]	England	Aim to present the inaugural global overview of AI in medical education through student perspectives	Mixed method	Online survey and focus groups Time: March 2020 Setting: Not reported Data analysis: Framework analysis	128 medical students	Three themes (1) AI comprehension (2) AI in medicine applications (3) preferred AI learning methods
Goetz CM [39]	United States	Exploring the perspectives of advanced-degree students on the use of virtual primary care physicians as patients	Qualitative	Focus groups Time: March and June in 2019 Setting: Two universities in the Midwest of the United States Data analysis: Content analysis	15 medical and computer science students	Three themes (1) advantages (2) disadvantages (3) future
Gonullu [37]	Türkiye	Examine medical students' views on individual and group clinical reasoning and decision-making using Virtual Patients	Qualitative	Semi-structured interviews Time: 2019–2020 academic year Spring Semester and 3rd term Setting: Not reported Data analysis: Content analysis	24 third-year medical students	Three themes (1) individual vs. Group Decision-Making in VP Simulations' (2) group Decision-Making *via* VP Simulations (3) VP simulations' impact on professional development'
Jafri L [41]	Pakistan	Investigate AI's influence on Clinical Chemistry lab professionals and	Qualitative	Semi-structured interviews Time: March to August 2022	7 physicians, 4postgraduate	Three themes (1) perceptions and considerations for AI integration

(*continued*)

Table 1. Continued.

Author, Year	Country	Aim of the study	Methodology	Data collection methods; Setting; Data analysis	Participants and setting	Findings
		identify strategies for educational adaptation.		Setting: The Section of Clinical Chemistry, Department of Pathology and Laboratory Medicine, Aga Khan University, Karachi, Pakistan Data analysis: Content analysis	students, and 1 laboratory staff member	(2) educational and curriculum adjustments (3)implementation techniques
Jebreen [27]	Palestine	Assess undergraduate medical students' attitudes towards AI in medicine, current training opportunities, the necessity for AI in curricula, and optimal teaching methods for AI.	Mixed method	Individual, in-depth interviews Time: June 15, 2022, to May 30, 2023 Setting: Private or public university in Palestine Data analysis: Inductive thematic analysis	15 undergraduate medical students	Four themes (1) lack of AI learning opportunities (2) need for AI in medical curricula; (3) optimism on AI's medical future; (4) anticipated challenges in AI medical education
Kaur A [38]	England	Assess perspectives of medical students and faculty on a tailored chatbot's applicability and constraints in medical education.	Qualitative	Face-to-face semi-structured interviews Time: March 2023 Setting: Warwick Medical School Data analysis: Thematic analysis	13 medical students and three staff members	Five themes (1) chatbot as simulation tool (2) chatbot for revision (3) year-group specific utility (4) education and assessment standardization (5) use and implementation challenges
Kong WJ [33]	China	Examine nursing undergraduates' genuine sentiments and AI project task-driven learning experiences to inform AI integration in nursing education	Qualitative	Face-to-face semi-structured interviews Time: September to December 2023 Setting: School of nursing Data analysis: Thematic analysis	14 nursing undergraduates	Three themes (1) emotional diversity with initial knowledge gaps (2) external support for individual growth during adaptation (3) final period expectations and suggestions post-results
Lane SH [34]	United States	Explore the societal impacts and applications of AI, recognizing its widespread presence and inherent potential	Qualitative	Survey Time: not reported Setting: Not reported Data analysis: Kiger and Varpio's thematic analysis	95 nurse educators	Four themes (1) generative AI's impact on faculty time (2) technology use in student learning (3) AI's role in teaching critical thinking (4) routine faculty task effects
Moldt JA [80]	Germany	Assesses medical students' knowledge of AI chatbots in healthcare contexts	Mixed method	Group work Time: not reported Setting: The University of Luebeck and the University Hospital of Tuebingen Data analysis: Mayring's qualitative content analysis	12 medical students	Four themes (1) user group (2) technical implementation (3) acceptance and trust (4) Use in medicine
Moldt JA [35]	Germany	Examine AI experiences, stakeholder awareness, and key AI topics in medical education to define student competencies.	Qualitative	Face-to-face or *via* videoconference semi-structured interviews Time: August 2022 to March 2023 Setting: Medical Faculty and the Faculty of Science of the University of Tübingen Data analysis: Content structuring analysis	6 lecturers, 9 clinicians, 10 students, 6 AI experts, and 7 institutional stakeholders	Four themes (1) possible curriculum contents, skills, and competencies (2) programming skills (3) curriculum scope (4) curriculum structure
Pucchio A [26]	Canada	Explore undergraduate medical students' perceptions of AI, educational opportunities about of AI in medicine, and the desired medium for AI curriculum delivery	Mixed method	Semi-structured interviews Time: October 2021 to December 2021 Setting: 11 Canadian medical schools Data analysis: Emergent thematic analysis	17 undergraduate medical students	Three themes (1) scarcity of AI learning opportunities (2) necessity for AI integration in medical curricula (3) optimism on AI's medical future
Shimizu I [36]	Japan	Analyzes the impact of GAI on medical education curricula and explores strategies for adaptation	Qualitative	Workshop Time: not reported Setting: Chiba University School of Medicine Data analysis: Content analysis	49 faculty and 6 students	Five themes (1) improvement of teaching and learning (2) improved access to information (3)inhibition of existing learning processes (4) problems in GAI (5) changes in physicians' professionality

(*continued*)

Table 1. Continued.

Author, Year	Country	Aim of the study	Methodology	Data collection methods; Setting; Data analysis	Participants and setting	Findings
Stewart J [28]	Australia	Examines medical student attitudes on AI, AI's role in healthcare, and AI education in medical curricula.	Mixed method	Online survey Time: the 7th of September 2021-the 7th of November 2021 Setting: Western Australian Data analysis: Grounded Theory	134 undergraduate medical students	Three themes (1) job security (2) career in radiology (3) further thoughts and comments
Kavadella A [44]	Cyprus	Assess the implementation of ChatGPT in the educational process	Mixed method	Online survey Time: February 2023 Setting: School of Dentistry, European University Cyprus Data analysis: Thematic analysis	77 dental students.	Three themes (1) ChatGPT collaboration and challenges (2) output quality (3) future possibilities and predictions
Deng A [31]	China	Explores the Current Applications of ChatGPT in Undergraduate Nuclear Medicine Education.	Mixed method	Online survey and Face-to-face semi-structured interviews Time: February 19, 2024 Setting: Second Clinical College of CQMU Data analysis: Methodically analyzed	25 undergraduate students and teachers	Three themes (1) enrich medical learners and educators encounter various challenges in education (2) ChatGPT shows substantial applicability and benefits in enrich medical education (3) respondents show a strong preference for ChatGPT, with interest in its educational uses

acquisition. In the era of big data, AI provides effective tools for managing and analyzing extensive data sets [32]. It also introduces new insights, fostering interest in learning and research, and enhancing innovation [33,34]. AI further assists in writing tasks, supporting non-native English speakers in article composition and ensuring logical coherence and accuracy through sentence restructuring and error detection [35].

> AI can be used to enhance learning since it will serve as a supportive learning material to generate answers to any questions regarding medicine or related fields. Also, AI makes learning fun [32].

Enhancing teaching efficiency and quality

AI is seen as a tool to improve teaching materials, boost instructor efficiency, save time, and enhance instruction quality, thus aiding effective student learning. Students view AI, like ChatGPT, as a means to get personalized responses, improve information retrieval efficiency, and reduce teacher repetition. AI's efficiency in repetitive tasks is anticipated to transform education and learning [9,34,36]. AI can generate test questions for daily exams with performance on par with human examiners. It offers efficient, standardized, and diverse questions, easing the teacher's workload and improving student learning efficiency [31].

> ChatGPT can sometimes help me to prepare lesson plans, teaching handouts and other teaching materials … …Combining ChatGPT and class, through the Q&A form to increase students' interest, can deepen the students' understanding of professional knowledge [31].

Enhancing clinical practice competence

AI Enhances Medical Student Confidence and Skills. Medical students view AI as a means to improve patient care quality and services. Those with limited clinical exposure often feel anxious due to their inexperience. AI, including chatbots, can aid in virtual patient interactions, benefiting introverted or less articulate students. Virtual practice with AI enables error-making and learning in a safe environment, overcoming clinical practice limitations and boosting practical skills and decision-making [25,37,38]. Medical students foresee that AI will enable the generation of uncommon clinical settings and patient cases in future clinical practice, enhancing adaptability and providing a wide range of experience for various scenarios. Moreover, AI is expected to save patients time and costs while eliminating emotional bias and human error, ensuring reliable and accurate data [39,40].

> It does mean we can practice in a safe space without it being stressful […] I don't think that it matters as much, because you're not taking someone's time and it would be less stressful [38].

Enhancing clinical decision-making and assisting data processing

Medical students anticipate that AI will offer suggestions and guidance in their future clinical practice. By critically evaluating AI-generated outcomes, they can inform medical decisions. In emergencies, AI can accelerate patient

Table 2. Quality assessment of included studies.

Study	1. Was there a clear statement of the aims of the research?	2. Is a qualitative methodology appropriate?	3. Was the research design appropriate to address the aims of the research?	4. Was the recruitment strategy appropriate to the aims of the study?	5. Was the data collected in a way that addressed the research issue?	6. Has the relationship between researcher and participants been adequately considered?	7. Have ethical issues been taken into consideration?	8. Was the data analysis sufficiently rigorous?	9. Is there a clear statement of findings?	10. How valuable is the research?	Score
Abid A, 2024	Y	Y	Y	Y	Y	CT	Y	Y	N	N	7.5
AraCTjo SM, 2024	Y	Y	Y	Y	Y	CT	Y	Y	N	Y	8.5
ArrCTzza E, 2024	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10
Balay-odao EM, 2024	Y	Y	Y	Y	Y	CT	Y	Y	Y	Y	9.5
Blease C, 2021	Y	Y	Y	Y	Y	CT	N	Y	Y	Y	8.5
Chen YY, 2023	Y	Y	Y	Y	Y	Y	CT	Y	Y	Y	9.5
Ejaz H, 2022	Y	Y	Y	Y	Y	N	CT	CT	Y	Y	8
Goetz CM, 2020	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10
GonCTllCT I, 2024	Y	Y	Y	Y	Y	CT	Y	Y	Y	CT	9
Jafri L, 2024	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	9
Jebreen K, 2024	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10
KaCTr A, 2021	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	9
Kong WJ, 2024	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10
Lane SH, 2024	Y	Y	Y	Y	Y	CT	Y	Y	Y	Y	9.5
Moldt JA, 2023	Y	Y	Y	Y	Y	CT	Y	Y	Y	CT	9
Moldt JA, 2024	Y	Y	Y	Y	Y	N	Y	Y	Y	CT	8.5
PCTcchio A, 2023	N	Y	Y	Y	Y	CT	Y	Y	Y	Y	8.5
ShimizCT I, 2023	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10
Stewart J, 2023	Y	CT	CT	Y	Y	N	Y	CT	Y	Y	7.5
Kavadella A, 2024	Y	Y	Y	Y	Y	CT	Y	Y	Y	Y	9.5
Deng, A, 2024	Y	Y	CT	Y	Y	Y	Y	Y	Y	Y	9.5

Note: Y = yes (1), N = NO (0), CT = Cannot tell (0.5).

Table 3. Overview of themes and subthemes.

Theme	Subtheme	Study findings	Studies
Shaping the Future: Current Trends in AI within Medical Education	The Gap in Artificial Intelligence Education	AI integration in medical education is lacking, resulting in students' limited understanding of AI applications in medicine.	[25–28]
	Actively Embracing	Medical students are receptive to AI applications and contemplate integrating AI studies into their future curricula.	[9,26–30]
	Relative Prioritization	Medical students believe that learning AI requires substantial effort and should not be a core part of the curriculum.	[26,27]
Advancing Medical Instruction: The Transformative Power of AI	Enhancing Medical Education Interaction and Innovation	AI provides more efficient human-computer interactions, enhances learning, and aids in fostering innovation.	[9,32–35]
	Enhancing Teaching Efficiency and Quality	Artificial Intelligence enhances the work efficiency and quality of educators, potentially revolutionizing daily examination practices.	[9,34,36,31]
	Enhancing Clinical Practice Competence	AI is capable of providing virtual scenarios and cases to assist medical students in practicing and accumulating experience.	[25,37–40]
	Enhancing Clinical Decision-Making and Assisting Data Processing	AI can provide guidance in clinical practice and enhance diagnostic speed and medical service quality through its data processing capabilities.	[27,32,35,40–42]
Navigating the Ethical Landscape of AI in Medical Education	Technological Dependence	Excessive use of AI may lead to dependency, adversely affecting the development of one's own capabilities.	[9,34,36,41]
	Data quality	The quality of data generated by AI may not be guaranteed, posing the risk of inaccuracies.	[31,35,43,44]
	Privacy Protection and Data Security	AI data protection concerns are voiced, fearing threats to personal privacy rights.	[27,32,39,40]
	Accountability Attribution	The issue of accountability for errors that occur with the use of AI is challenging to define.	[32,39]
	Empathy	AI lacks emotional nuances for empathy, unlike human interactions.	[26,38,39]
	Technology Acceptance	Patients, due to their limited understanding of AI, may reject the involvement of AI in their treatment plans.	[40,42]
	Autonomy Concerns	AI's robust capabilities have sparked concerns regarding potential future displacement of human labor.	[26,28,32,39–44]
Fostering Synergy: Integrating Artificial Intelligence in Medical Curriculum	Integrating AI into Medical Education	In medical education, effective AI integration is facilitated through comprehensive courses covering theory, skills, and practical applications, enhancing students' AI comprehension, ethical data handling, and AI application.	[9,26,30,33,35,37,41]

diagnosis [32,40,41]. AI's data processing capabilities streamline repetitive tasks, facilitating medical data digitization. This enhances data storage and analysis efficiency, decreases labor intensity, and frees up resources for other tasks, ultimately boosting medical service quality [27,35,41,42].

> It may reduce the amount of manual handling. It can also be beneficial for the patient if AI is used for detection and diagnosis of pathology [42].

Navigating the ethical landscape of AI in medical education

Technological dependence

Excessive reliance on AI is an issue in current medical education. It may foster laziness and an overreliance on the formidable capabilities of AI, thereby affecting the development of writing skills, critical thinking, and diminishing the ability for independent thought [9,34,36,41]. Researchers contend that student dependence on AI for academic tasks hinders accurate teacher assessment of their capabilities and fosters superficial learning, reducing their learning capacity and critical thinking abilities [28].

> Students won't actually learn the information if they use the tools for their schoolwork [34].

> Students will have less opportunity to think for themselves [36].

Data quality

AI-generated content accuracy is a critical concern in medical education. Dependent on training data quality and representativeness, AI's veracity is questioned by students, who doubt its ability to offer precise resources and specific query responses [31]. AI's varying responses to differently phrased questions may introduce data biases, risking incorrect outcomes. Inadequate question phrasing or unclear descriptions can lead to superficial and incomplete answers [35,43]. Furthermore, AI-generated answers cannot be guaranteed to be up-to-date; they only reflect information

available up to a certain point in time, which, although often close to the present, may still be outdated [44].

> I would not say that it demonstrated a very deep understanding of the topic, but I think with even more questions being asked, then the text could essentially show a deep understanding of the topic [44].

Privacy protection and data security

Medical students voice privacy concerns with AI use, fearing unauthorized access, misuse, or theft of their and patients' data. They also worry about exclusion from AI-assisted decision-making processes, remaining uninformed about AI recommendations. Participants emphasize the need for stringent security systems with transparent, secure data storage and protection, capable of automatically detecting risks. They also call for transparent, secure data management regulations to build trust in AI and protect data and personal information security [27,32,39,40].

> My concern is about confidentiality and ethical issues of the AI use [39].

Accountability Attribution

Participants have raised the question of who should be held accountable for errors made by artificial intelligence. Determining liability for errors that arise from the use of AI becomes complex, involving the apportionment of responsibility among software developers, healthcare professionals, and patients [32,39].

> …it's worse if a computer makes the mistake because then the idea is, well, who do you sue? Whose fault is it? [39]

Empathy

AI's integration into medicine raises doubts about its ability to understand human emotions. Medical students argue that robots lack the empathy needed to fully comprehend emotional nuances, affecting their judgment [39,40]. Medical students argue that practicing with artificial intelligence (such as interacting with virtual patients or chatbots) does not allow them to feel the emotions of the other party as they would in real human interactions. They merely feel as if they are conversing with a screen, which they believe does not foster their empathetic abilities [26,38].

> A larger part of medicine, you need to be compassionate, empathetic, maintaining a patient's dignity which I feel would be lost completely, if you're interacting with a screen [38].

Technology acceptance

Artificial intelligence may diminish patient adherence to treatment. Due to their limited understanding of AI, patients may harbor doubts about the correctness of decisions made by AI. When AI recommendations conflict with a physician's judgment, patients are more inclined to trust the doctor, thereby potentially rejecting treatment plans that involve AI [40,42].

> It is a little worrying, I don't want the patients' health in the (metaphorical) hands of AI [42].

Autonomy concerns

AI is unlikely to fully replace humans, as it serves as a supportive tool with questionable accuracy and lacks empathy. It assists medical students, educators, and clinicians by providing references, but they retain decision-making authority and must critically assess AI's data and conclusions [28,32,39,40,43]. Furthermore, due to a lack of understanding of AI, patients may also resist the use of AI [39].

> Artificial intelligence/machine learning can't replace psychotherapist/mental health professionals [40].

As technology continues to evolve and the capabilities of artificial intelligence grow more robust, the dependency of students, educators, and clinicians on AI is increasing. A minority of participants express concern that their jobs may gradually be supplanted by artificial intelligence [26,28,42,44].

> 'the power it holds is unpredictable and the work of doctors could be compromised,' 'maybe we will live one day that AI robots could even replace dentists' [44].

Fostering synergy: Integrating artificial intelligence in medical curriculum

AI integration in medical education is best achieved through targeted courses that go beyond theory to include skill training and practical application. These courses can be delivered *via* video, audio, or in-person instruction and should cover essential AI knowledge, ethics, data literacy, and associated opportunities and risks. Such courses can address apprehensions about AI and equip students and healthcare providers with the necessary skills and knowledge for data management and AI application, ensuring ethical patient data handling and a smoother AI integration in medical education [9,26,30,35,37,41]. Participants who have completed AI courses have reported an enhanced understanding of AI, including its functionalities and applications in learning or professional contexts [30,33].

> I feel that I learned AI/ML fundamentals, am now able to better read and understand AI/ML medical literature, and have thought through the essential design elements of an AI/ML proposal [30].

Discussion

This study aims to evaluate current AI usage in medical education by synthesizing qualitative research and examining perspectives of learners, instructors, and practitioners on AI integration in their field.

Although the use of artificial intelligence in medical education has seen a significant increase since 2016 [45], however, the application of artificial intelligence in the field of medical education is currently not widespread [46,47]. Its application varies by country due to differences in development, economy, and culture. Developed nations use AI to stay competitive and boost growth, while developing ones focus on using it to meet community needs

due to resource and infrastructure constraints [48]. Large language models, like ChatGPT, trained predominantly on English data, may not grasp healthcare-specific terminologies and practices across cultures, potentially rendering educational content unsuitable for students from diverse backgrounds [49]. Qualitative studies in China reveal low ChatGPT prevalence, necessitating VPNs and facing challenges in acquiring access rights [31].

Medical students maintain a positive attitude towards AI and wish to engage with knowledge and skills related to artificial intelligence in the future [50]. AI's robust capabilities offer multifaceted benefits in medical education. Research confirms its high accuracy in medical exams and qualification tests, often providing multi-perspective correct answers, suggesting its potential to bolster self-directed learning [51,52]. Furthermore, the application of programs such as virtual patients and chatbots has greatly nurtured the clinical reasoning and practical skills of medical students, aiding in improving their clinical experience and the ability to communicate with patients [53]. Prior studies suggest AI's data processing and exam sensitivity limitations have hindered its use in curriculum and student assessment [54]. Yet, this study shows AI has effectively participated in exams and supported instructors in devising questions [55]. This may imply that the potential of artificial intelligence in medical education is growing. AI's advantages in writing are well-established, particularly in medical education, where it boosts academic writing and research productivity for students, educators, and clinicians. It aids in material integration, drafting, and error-proofreading, enhancing the quality of written work, notably for non-native English speakers [56–58]. However, assistance with the substantive content of a paper is considered an unethical act and an academic misconduct [59]. Although large language models (such as the GPT series and LLaMA series) have made progress in handling complex issues, their performance on simple tasks still has issues, and their avoidance behavior in high-difficulty tasks has not increased [60]. AI can introduce new perspectives and ideas, enhancing innovation, but it also raises concerns that users may become overly reliant on AI for daily learning and work. More importantly, this could be detrimental to the development of innovative thinking [61].

AI in medical education triggers ethical concerns, including privacy issues and responsibility allocation, even with health education robots perceived as low-risk [62]. Considerations include the potential use of personal data and information during the application of AI, the presence of unauthorized data in predictive analytics, and the possibility of cybersecurity issues such as data breaches due to hacking incidents [63], all of which pose significant moral issues [64]. In AI, private companies lead in tech development and application. Public-private partnerships often compromise privacy due to insufficient protection. Advances in algorithms can de-anonymize health data, further undermining privacy. Regulatory measures lag behind technological progress, exacerbating privacy protection issues [65]. Attribution of responsibility for erroneous outcomes resulting from the use of artificial intelligence is complex and fraught with ethical dilemmas, with accountability currently challenging to ascertain [66]. Some scholars argue that if an AI system has design or implementation flaws that lead to medical errors or patient harm, the developers or manufacturers may need to take responsibility [67]. Researchers contend that healthcare providers must be accountable for harm caused by misinterpreting AI-generated information or advice, as they are obliged to independently evaluate AI outputs [68]. Concerns remain about AI-generated content's accuracy, with studies showing challenges in sourcing ChatGPT-like model outputs and inaccuracies in provided references. Despite continuous updates, AI content may not reflect the latest information [69]. Due to the incompleteness and bias in the data sources used to train artificial intelligence, distortions in the output content can occur. Such distortions and biased information may lead to unintentional prejudice among medical students [70]. Consent crucial in AI healthcare, where patients may not realize AI's role in decisions or its advice. Autonomy in AI use can infringe on rights. Studies back AI as an aid, not replacement, for medical staff [71,72]. However, a small segment of the population has also voiced concerns. Some research suggests that this worry is based on a misunderstanding stemming from popular science fiction beliefs [73], but it may also be related to the robust capabilities demonstrated by artificial intelligence.

AI integration into medical curricula benefits students and educators, enhancing AI application in medical education. Courses on AI have shown positive results in teaching its use [30]. To enhance these effects, educators should possess foundational knowledge of artificial intelligence pertinent to learning and teaching [74]. A comparative quasi-experimental study explored the impact of AI courses within nursing programs on students' readiness for medical AI, revealing that AI nursing curricula have a positive effect on students' preparedness for AI technology [75]. Students who have not been exposed to artificial intelligence in the field of medicine are also unlikely to proactively engage with the applications of AI in medical practice later on [76]. Clinical practitioners commonly lack AI knowledge, unpreparedness for AI integration poses patient risks [77]. A survey of clinical practitioners revealed that 21.3% of the participants indicated that they had never received any formal education in artificial intelligence during their studies or employment [78]. Exposure to artificial intelligence-related courses during their academic years establishes a foundation for their future use of AI-assisted technologies in hospital settings.

Strengthens and limitations and future research

This study is the first to examine attitudes towards AI in medical education from the viewpoints of students, educators, and professionals, analyzing current status, benefits, drawbacks, ethics, and curricula. Focusing on post-2020 literature ensures currency but may exclude earlier key works. Future research should consider a broader timeframe to detect AI's evolving role in medical education. Limiting to English databases might introduce bias, but including 13 countries, predominantly non-English speaking, somewhat mitigates this methodological limitation. Future studies should include non-English databases for a global AI in medical education perspective.

Implications for research, policy, and schools

AI in medical education offers benefits but also poses risks that must be managed. It's essential for medical students and educators to be aware of AI's applications, including its strengths and weaknesses. Medical schools should survey AI use among their community and provide relevant training. This training should be practical, integrating AI into clinical and classroom settings. For non-English-speaking regions, improving English proficiency can enhance AI application capabilities. Ethical use of AI is vital; thus, medical schools should emphasize ethical considerations and social responsibility in AI education, ensuring it aids rather than replaces human professionals [79].

Conclusion

The application of AI in medical education holds broad prospects, but its advancement should be approached with caution. In the field of medical education, AI has the potential to enhance interactivity and innovation, improve teaching efficiency and quality, clinical practice skills, clinical decision-making, and assist in data processing. However, there are currently issues such as the potential for technological dependency and the quality of data generated. More concerning are ethical issues related to privacy rights, data security, and the attribution of responsibility. These obstacles hinder the integration of AI with medical education. Future collaboration between medical educators, medical schools, and policymakers is essential to overcome the barriers to the use of AI in medical education, allowing AI to play a more effective role in this field.

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