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Mapping the use of artificial intelligence in medical education: a scoping review

Erwin Hernando Hernández Rincón[1*], Daniel Jimenez[2], Lizeth Alexandra Chavarro Aguilar[2], Juan Miguel Pérez Flórez[2], Álvaro Enrique Romero Tapia[3] and Claudia Liliana Jaimes Peñuela[1]

Abstract

Introduction The integration of artificial intelligence (AI) in healthcare has transformed clinical practices and medical education, with technologies like diagnostic algorithms and clinical decision support increasingly incorporated into curricula. However, there is still a gap in preparing future physicians to use these technologies effectively and ethically.

Objective This scoping review maps the integration of artificial intelligence (AI) in undergraduate medical education (UME), focusing on curriculum development, student competency enhancement, and institutional barriers to AI adoption.

Materials and methods A comprehensive search in PubMed, Scopus, and BIREME included articles from 2019 onwards, limited to English and Spanish publications on AI in UME. Exclusions applied to studies focused on postgraduate education or non-medical fields. Data were analyzed using thematic analysis to identify patterns in AI curriculum development and implementation.

Results A total of 34 studies were reviewed, representing diverse regions and methodologies, including cross-sectional studies, narrative reviews, and intervention studies. Findings revealed a lack of standardized AI curriculum frameworks and notable global discrepancies. Key elements such as ethical training, collaborative learning, and digital competence were identified as essential, with an emphasis on transversal skills that support AI as a tool rather than a standalone subject.

Conclusions This review underscores the need for a standardized, adaptable AI curriculum in UME that prioritizes transversal skills, including digital competence and ethical awareness, to support AI's gradual integration. Embedding AI as a practical tool within interdisciplinary, patient-centered frameworks fosters a balanced approach to technology in healthcare. Further regional research is recommended to develop frameworks that align with cultural and educational needs, ensuring AI integration in UME promotes both technical and ethical competencies.

Keywords Artificial intelligence (AI), Medical education, Curriculum development, Ethical training, Undergraduate medical education (UME), Experiential learning

*Correspondence:
Erwin Hernando Hernández Rincón
erwinhr@unisabana.edu.co
Full list of author information is available at the end of the article

Introduction

In recent decades, the integration of digital technologies in healthcare, commonly referred to as E-Health, has revolutionized the delivery of medical services [1]. E-Health encompasses a wide range of tools, including electronic health records, mobile health applications, telehealth, and remote monitoring platforms, all of which have significantly improved the efficiency of healthcare systems and optimized patient care globally [2]. These advancements have enhanced accessibility and personalization of healthcare, marking a significant shift in how patients and healthcare professionals interact with information and services [3, 4]. The COVID- 19 pandemic further accelerated the adoption of telehealth, including teleconsultations and remote monitoring, which emerged as essential components of healthcare delivery [5]. Besides expanding access to care, telehealth has provided new opportunities for medical education, allowing students to gain clinical experience through remote simulations and consultations, regardless of geographical constraints [6].

Amid this ongoing digital transformation, artificial intelligence (AI) has become a transformative tool in healthcare, with applications ranging from clinical decision support systems to diagnostic algorithms and personalized treatment solutions [7–9]. AI refers to the use of computational algorithms and machine learning techniques that enable systems to analyze data, recognize patterns, and perform decision-making tasks traditionally carried out by humans. In medical education, AI encompasses technologies such as clinical decision support systems, intelligent tutoring systems, and natural language processing tools that enhance learning by providing personalized feedback and improving diagnostic reasoning [9]. AI has demonstrated the capacity to analyze vast amounts of health data and generate precise predictions, improving both efficiency and accuracy in clinical care [10]. In specialties like radiology, AI has shown potential to perform comparably to experienced clinicians, suggesting that it could complement healthcare delivery and decision-making processes [11]. However, the rapid integration of AI also necessitates an evolution in the competencies required of healthcare professionals. As AI becomes an indispensable part of medical practice, it is crucial for future physicians to develop the skills necessary to use these technologies effectively and ethically [12].

AI is increasingly used in both clinical decision-making and medical education, but these applications serve distinct purposes. In clinical settings, AI supports tasks such as diagnostic imaging, predictive analytics, and patient management by assisting healthcare professionals in decision-making. In contrast, in medical education, AI is used primarily to enhance learning through technologies such as intelligent tutoring systems (ITS), virtual simulations, adaptive learning platforms, and automated assessment tools. While some AI-driven tools, like clinical decision support systems (CDSS), may overlap, this review specifically focuses on AI's role in enhancing medical education rather than its direct application in patient care [7–9].

The World Health Organization (WHO) has established ethical principles to guide AI applications in healthcare, emphasizing the importance of human autonomy, transparency, and accountability to ensure AI benefits patients and communities while minimizing risks associated with surveillance, discrimination, and inequitable access [13]. In the context of medical education, AI is already enhancing learning experiences and preparing students for an AI-driven healthcare environment. Specific applications include Intelligent Tutoring Systems that provide personalized learning for decision-making, AI-assisted learner assessments using Latent Semantic Analysis and Natural Language Processing to grade and provide feedback on clinical cases, and AI-powered Chatbots that help students review medical literature, prepare for exams like the United States Medical Licensing Examination (USMLE), and develop critical thinking and communication skills [14]. The incorporation of these digital learning tools—such as clinical simulations, online classes, and collaborative platforms—has already enhanced the accessibility of medical education globally [15]. Moreover, AI-driven personalized learning platforms create adaptive learning paths for students, while Virtual Reality simulations powered by AI offer surgical training experiences that were previously limited to in-person settings, contributing to skill development without geographical constraints [14]. Despite these advancements, the integration of AI into medical curricula remains insufficient, with most programs failing to address the specific competencies required for students to navigate AI-driven clinical environments effectively. This has created a critical gap in medical education, leaving future healthcare professionals underprepared to utilize AI technologies in practice and to address their associated ethical and operational challenges [16]. In several academic circles, it is suggested that rather than training specific AI competencies, the focus should be on strengthening transversal skills, including autonomous learning, to facilitate the gradual incorporation of emerging technologies and other evolving components [17, 18].

Despite the increasing use of AI in clinical practice, medical education has often struggled to keep pace with these advances. To address this gap, this scoping review maps the integration of AI in undergraduate medical education (UME), focusing on three key areas: (1) the development and implementation of AI-related

curricula, (2) the impact of AI-driven education on student competency development, and (3) institutional and systemic barriers that hinder AI adoption. By identifying challenges and emerging trends, this review aims to provide insights into the current state of AI education in UME and propose evidence-based recommendations for its effective integration.

Materials and methods

A scoping review was conducted in October 2024, following the methods of Arksey et al. [19] and Levac et al. [20], and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Extension for Scoping Reviews [21]. The research question guiding this scoping review is: How is artificial intelligence (AI) currently integrated into undergraduate medical education (UME), and what are the key challenges and trends in AI-related curriculum development, student competency enhancement, and institutional adoption?

The Arksey and O'Malley framework involves five key steps [19]: identifying the research question, identifying relevant studies, selecting studies, charting the data, collating, summarizing, and reporting results. This review adhered to the five steps, with a structured approach to ensure methodological rigor.

The research question was defined to explore the role of artificial intelligence in undergraduate medical education, guiding the search strategy and inclusion criteria. Relevant studies were identified through systematic searches in selected databases, and the inclusion process was detailed in Sect. 2.3. The data charting stage involved extracting key information on study objectives, methods, findings, and implications, ensuring consistent and comprehensive documentation. The results were then analyzed and synthesized as described in Sect. 2.5.

Search strategy and data charting

Studies were identified by searching PubMed, Scopus, and BIREME for articles pertinent to our research question. The search covered studies from 2019 onwards, with a combination of Medical Subject Headings (MeSH) and Health Science Descriptors (DeCS), including terms such as: "Artificial Intelligence"[MeSH] AND"Education, Medical"[MeSH]. The search was restricted to publications in English and Spanish from January 1, 2019, onwards to ensure both the relevance of the data and a wider geographical inclusion.

The choice of these three databases was based on their relevance to the study's scope and their comprehensive coverage of medical and health sciences literature. PubMed was selected for its focus on biomedical research, Scopus for its interdisciplinary content and broader citation data, and BIREME for its inclusion of Latin American and Caribbean studies, ensuring geographical diversity. Additional relevant studies were located by hand-searching the reference lists of the included articles, and the search was updated regularly to include any new research until the completion of the review (Fig. 1).

Study selection

All retrieved citations were imported into Rayyan [22], an online tool designed for managing systematic reviews, for efficient study selection and data management. Study selection was performed in three steps (Fig. 1):

1. Initial Screening: Titles and abstracts were independently screened by three reviewers, DJ, JP, and LC, using Rayyan to determine eligibility based on predefined inclusion and exclusion criteria. Any disagreements were resolved through discussion.
2. Criteria Refinement: After the initial screening, the inclusion and exclusion criteria were refined post hoc to ensure the selection process accurately aligned with the research objectives.
3. Full-Text Screening: Eligible articles were then assessed at the full-text level by two reviewers (DJ, LC). Articles were included if they broadly discussed AI in undergraduate medical education (UME).

Inclusion and exclusion criteria

Studies were included if they:

- Discussed the integration of artificial intelligence in undergraduate medical education.
- Included primary research, perspective, or commentary articles with full-text availability.
- Addressed AI within the UME context, specifically targeting machine learning, deep learning, natural language processing, clinical decision support systems, intelligent tutoring systems, and AI-driven simulation tools.

Studies were excluded if they:

1. Focused solely on postgraduate or continuing medical education. However, studies discussing AI applications that are relevant to both UME and postgraduate training—such as clinical decision-support systems—were included if they explicitly addressed their role in undergraduate education.
2. Studies primarily focused on AI for clinical decision-making (e.g., AI-assisted diagnostics, treatment recommendations, or patient monitoring) were

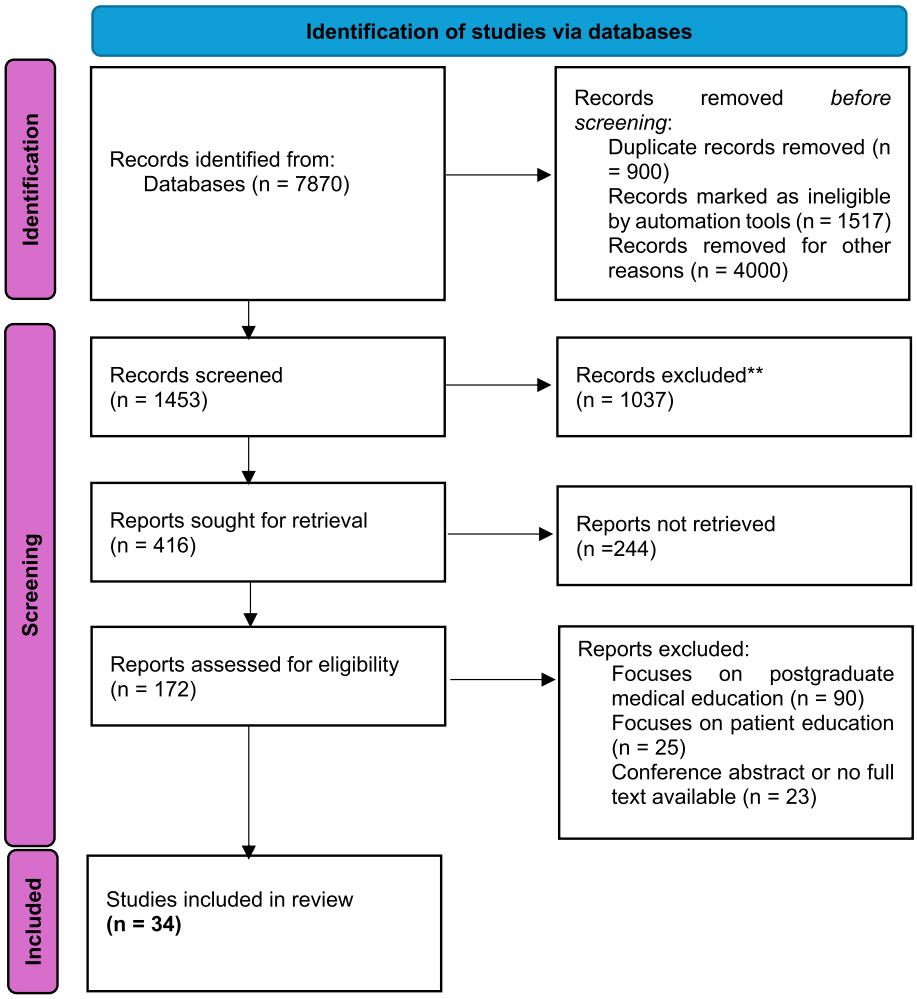

Fig. 1 Methods flow chart

excluded unless they explicitly addressed their role in medical education.

3. Discussed the application of AI for allied health professionals or osteopathic medicine.
4. Excluded studies that addressed AI in the context of patient education.
5. Were conference abstracts or lacked full-text availability.

Data extraction

Data extraction was performed using a structured data charting form (Fig. 2). The form, developed iteratively and tested by the review team, aimed to capture essential elements. The charting form was refined throughout the process to ensure consistency and relevancy of data extracted. The data extraction process was conducted by three reviewers (DJ, LC, and JP), who extracted data from all full-text articles. Any disagreements during data extraction were resolved through consensus discussions. The data charting was conducted iteratively, allowing continuous refinement of the form to better capture emerging themes in the literature.

Collating, summarizing and reporting results

The study demographics were summarized using descriptive statistics to provide an overview of the types, locations, and focus areas of the included studies, enabling the identification of trends and gaps.

Thematic analysis was systematically applied to qualitative data to identify key themes. The process began with a thorough review of the data, assigning descriptive codes to capture recurring topics aligned with the study objectives.

Two independent reviewers initially coded the data to ensure reliability and minimize bias. Descriptive codes were then clustered into broader pattern codes, consolidating findings into overarching themes. Any

AI Implications in Medical Education	Articles	Subthemes
Impact of AI on Medical Education	(23–27)	Interdisciplinary AI Education in Medical Curricula • Promote interdisciplinary learning by integrating AI concepts into medical education, fostering critical thinking and collaboration across diverse fields of study, including medicine and natural sciences (27). Balancing Technological and Human Aspects of Medicine • AI must be balanced with human-centered, hands-on medical practice to avoid reducing patient care to algorithmic decision-making (26). Redesigning Medical Curricula for AI Integration • Medical education must shift from information acquisition to knowledge management, with a focus on using AI for precision medicine and enhancing physician-patient communication (3). AI-Enhanced Learning and Training Efficiency • AI-integrated models could accelerate medical knowledge acquisition and streamline training, making education more efficient and accessible (24). AI's Role in Evolving Medical Education Frameworks • AI-driven changes require a shift in medical education, focusing on digital literacy and collaboration with patients to ensure ethical and effective use of AI (23).
AI in Curriculum Development	(28–32)	Incorporating AI Competencies into Medical Curricula • AI competencies should become an integral part of the mandatory medical school curriculum to equip future physicians with the necessary skills to interact with AI systems and make informed decisions. (28) Staged Model for AI Integration in Medical Education • A staged approach to AI education is recommended, with students learning AI fundamentals in pre-clinical years and applying AI-based clinical applications in later clinical years. (29) Ethical Foundations for AI Integration in Medical Education • AI education in medical curricula must prioritize ethical considerations, ensuring that future physicians understand the implications of AI, including patient confidentiality, algorithmic biases, and informed consent. (30) Ethical and Purposeful Use of AI in Medical Education • Medical students must be trained to use health data and AI technologies in alignment with ethical and legal standards, ensuring the appropriate application of AI in clinical practice and safeguarding patient records for AI processing. (31) Preparing Medical Students for AI Integration in Medicine • Medical students need structured education on AI to navigate the evolving healthcare landscape, ensuring they understand AI's role while maintaining ethical standards and the humanistic aspects of patient care (32).
Perceptions and Attitudes towards AI	(33–37)	Exploring AI in Medical Education in Nigeria (45) • Medical students in Nigeria show both excitement and apprehension towards AI, with a significant number fearing that AI could diminish physicians' skills and dehumanize healthcare (35). AI in Canadian Medical Education • Canadian medical students believe AI will be integral to their careers, yet a majority feel that AI education is insufficient, highlighting the need for formal AI training in the curriculum (37). AI Acceptance in India's Medical Education • While Indian medical students demonstrate strong interest in AI integration, they express concerns about overreliance on AI and the risk of losing empathy in patient care (34). Perceptions of AI in UK Medical Education • UK medical students recognize the importance of AI in healthcare but feel inadequately prepared, especially with respect to radiology, where they fear AI may reduce career opportunities (36). AI in Medical Education across Arab Countries • Arab medical students, despite their limited AI training, acknowledge the potential of AI to revolutionize radiology and advocate for its inclusion in medical curricula (33).
AI Applications in Teaching and Learning	(46–49,55,56)	Teaching, Learning and Assessing Anatomy with Artificial Intelligence: The Road to a Better Future • AI can be used for plagiarism detection, curriculum design, feedback on practice, simulated clinical sessions, creating dissection videos, and supporting online assignments (49) Artificial intelligence and medical education: application in classroom instruction and student assessment using a pharmacology & therapeutics case study • AI significantly enhances medical education through improved self-study support, integrated interdisciplinary learning, and relevant aspect identification, despite challenges in multiple-choice question construction and standardization (46). Difficulties of artificial intelligence in medical education • The formality and rigidity of AI models can make it difficult to teach anatomical "uncertainty," so it is recommended that the anatomy education community collaborate with developers to integrate this variability into AI tools (56). • AI generates adequate test items but requires human review to ensure accuracy and avoid errors. Limitations include the possibility of memorizing answers and extracting data from unauthenticated sources. It is suggested that teaching staff be trained in the use of AI and that the security of these tools be further improved (55). • Using ChatGPT to create simulated clinical cases has been successful in diversifying topics but has been presented with errors in accuracy and cultural and medical detail (47). Using artificial intelligence as an innovative learning strategy • An innovative program allowed medical students to participate in labeling lung ultrasound image data, improving understanding of AI and medicine (47) . • The use of AI could improve self-assessment, data analysis, and hands-on training with clinical simulations to automate processes, reduce risks and costs, and adapt to post-pandemic educational changes, incorporating advanced technology into medical education (55). • The mobile app offers personalized recommendations and functionalities such as tournaments, rankings and challenges to foster student collaboration and leadership (48).
Use of Chatbots and ChatGPT in Medical Education	(39–45,57)	Potential of AI language models in clinical decision making • ChatGPT can help formulate article outlines, paraphrase texts, and speed up literature review. However, there are challenges with verifying AI-generated sources and citations (57) Weaknesses arising from the use of chatbots in medical education • Misuse of ChatGPT can compromise academic integrity and lead to over-reliance, raising the need for policies and strategies to mitigate these risks (44). • Chatbots are underused in UK medical education due to a lack of development appropriate to student needs, lack of promotion by institutions, and students' lack of awareness of the potential benefits (45). Opportunities for integrating chatbots in clinical care, teaching and research • Chatbots can be useful in the early years of medical training, providing a safe environment for learning before direct clinical contact (41). • By providing accurate medical guidance, they reduce costs and improve patient outcomes. ChatGPT-4 could be integrated into patient simulations and personalized learning, as well as assisting in research production (41). • The integration of tools such as ChatGPT can reduce knowledge gaps, expand differential diagnoses, question medical axioms and support decision making in acute care and complex cases (40). • ChatGPT facilitates the dissemination of popular information, can marginalize local cultures and languages, affecting cultural diversity. Furthermore, its use could open new opportunities in areas such as medical AI and information management (39). • Chatbots could be used as patient simulators, review tools or to standardize exams, thus improving self-learning and reducing tutor intervention (57).
Ethical Considerations and Challenges	(29,44,50,51,57)	Ethical perceptions surrounding the use of artificial intelligence in medical education • The ethical management of AI is crucial to ensure its responsible use and equitable distribution of benefits, as access to the advantages of AI is not uniformly available (51) • There are many ethical and legal obstacles surrounding the implementation of AI in healthcare, an example of this is the negative perception of AI due to its lack of human essence (57) • It is necessary to critically and ethically evaluate the use of artificial intelligence, despite the convenience of obtaining easily generated information (44). • Awareness of the misinformation generated by AI about biomedical knowledge and the pathophysiology of diseases must be generated to avoid its use (29,50)
AI in Assessment and Feedback	(47,49,52,53)	Anatomy Revolution with AI • AI revolutionizes anatomy education through 3D virtual reality, aiding in curriculum design, feedback, and online learning, though logistical considerations are essential (49). AI in Pharmacology Education • AI supports medical education by enhancing self-study, offering an integrated interdisciplinary approach, and facilitating key learning aspects. However, it faces challenges with multiple-choice question construction and standardization (47). Personalized Education with AI • Precision education, driven by AI, offers personalized and effective educational experiences while addressing traditional limitations, though it must navigate challenges in transparency, privacy, and bias propagation (53). MEKAS System in Otorhinolaryngology • The MEKAS system significantly enhances self-learning in otorhinolaryngology, validated by substantial improvement in results and high satisfaction (52).
The Future of AI in Medical Education	(25,50,54)	Curriculum Redesign in the AI Era • A complete overhaul of medical school curricula is essential to focus on the effective use of AI in medicine (25). Ethical Framework for AI Education • Establishing a robust ethical framework is vital for ensuring safety, privacy, and equity in the integration of AI in healthcare (50). Professional Development with AI. • Evaluating and promoting AI in healthcare education can significantly enhance learners' comprehension and skills (54).

Fig. 2 Key themes and implications of artificial intelligence in undergraduate medical education

discrepancies in coding were resolved through discussion, with a third reviewer involved in cases where consensus was not reached. This refinement process was iterative, ensuring themes accurately represented the findings while aligning with the research focus on AI in undergraduate medical education (UME).

To enhance reliability and comparability, themes were visualized using thematic matrices, allowing for a systematic identification of similarities, differences, and overarching patterns across studies. The thematic structure was reviewed by all authors to ensure consistency and coherence in relation to the study's objectives.

Additionally, to assess the inter-reviewer agreement, Cohen's kappa coefficient was calculated at key stages of the review process:

Study selection

Cohen's kappa was applied to measure agreement between reviewers during the title/abstract and full-text screening stages, achieving a final inter-rater agreement of 0.85, indicating near perfect agreement.

Thematic coding

A subset of studies was independently analyzed by two reviewers to assess coding reliability. The agreement on initial codes was quantified (kappa = 0.82), and discrepancies were resolved through discussions.

Final theme validation

All themes were cross-checked by multiple reviewers to confirm coherence and relevance, ensuring a robust interpretation of findings.

Results

Study characteristics

Our search identified 7,870 records, of which 34 full-text articles were included in our final analysis. The most prevalent study type was the cross-sectional study (n = 6, 17.6%), followed by narrative reviews (n = 5, 14.7%). Interdisciplinary teaching and research projects, as well as educational intervention studies, each accounted for 4 articles (11.8% each). Opinion articles made up 8.8% of the studies (n = 3). Other study types, including conceptual analysis, pedagogical discussions, exploratory case studies, commentary, and quasi-experimental studies, each represented 5.9% of the total with 2 studies per category. Additionally, e-Delphi studies, prospective analyses, and qualitative exploratory studies were less common, each comprising 2.9% of the total with 1 study in each category.

In terms of geographical distribution, as shown in Fig. 3, the United States contributed the highest number of studies (n = 6, 15%), followed by Canada (n = 4, 10%) and Australia (n = 3, 7.5%). There was also representation from countries such as Germany, the Netherlands, Turkey, China, and the UK, each with 2 studies (5%). Single studies came from various locations, including Oman, Bahrain, Malaysia, Brunei, Mexico, Nigeria, India, Chile, Poland, Egypt, and Taiwan (2.5% each).

The publication years varied, as illustrated in Fig. 4, with the majority of studies from 2024 (n = 11, 27.5%) and 2023 (n = 10, 25%). Other years included 2022 (n = 7, 17.5%), 2020 (n = 4, 10%), and 2019 (n = 2, 5%). This diverse range of studies highlights the varied methodological approaches and global representation in the examination of artificial intelligence in medical education.

Impact of AI on medical education

Five studies [23–27] explored the impact of AI on medical education, emphasizing the need for interdisciplinary learning by integrating AI concepts into medical curricula. These studies highlighted the importance of collaboration across fields such as medicine, natural sciences, and technology [27]. A recurring concern was the need

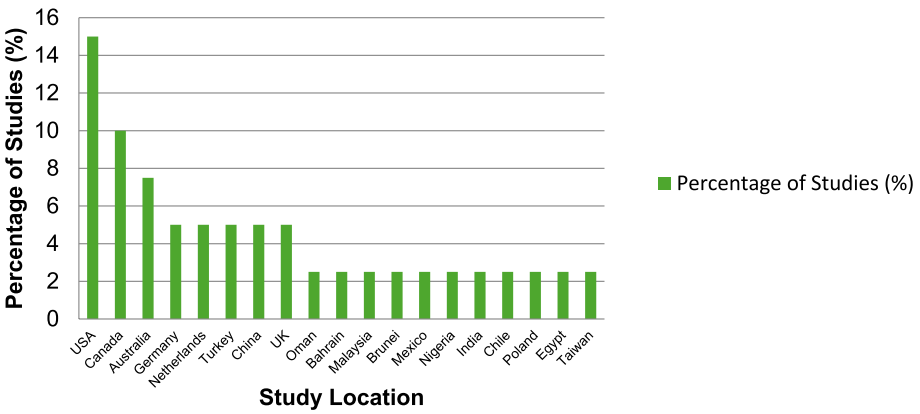

Fig. 3 Distribution of studies by location

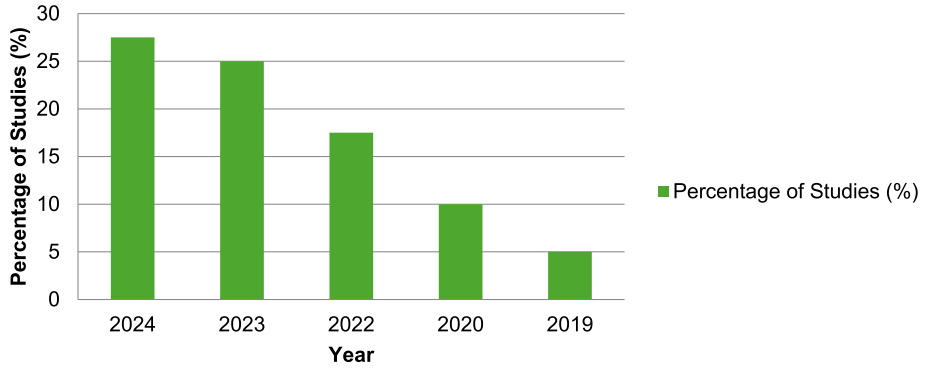

Fig. 4 Distribution of studies by year of publication

to balance technological and human aspects of medicine, ensuring that AI supports patient-centered care rather than replacing it with algorithmic decision-making [26]. Some studies also noted that AI could enhance training efficiency and medical knowledge acquisition, making education more accessible [24]. Furthermore, the integration of AI in curricula was seen as vital to equip students with digital literacy and skills necessary for effective patient collaboration [23].

AI in curriculum development

Six studies [28–32] discussed the integration of AI competencies into medical curricula, suggesting they become a mandatory component of medical education to prepare physicians for AI-based clinical decision-making [28]. A staged model was recommended, where students learn foundational AI concepts in pre-clinical years and apply them in clinical contexts later [29]. The studies also emphasized ethical education, highlighting the need to teach students about patient confidentiality, algorithmic biases, and informed consent [30]. Training programs must ensure that medical students use AI technologies responsibly, aligning with legal and ethical standards [31]. Preparing students to navigate AI's role while maintaining ethical and humanistic care was deemed essential [32].

Perceptions and attitudes towards AI

Four studies [33–37] examined medical students' attitudes towards AI across different regions. In Nigeria, students expressed both excitement and concern, fearing that AI could undermine physicians'skills [35]. In Canada, students saw AI as crucial for their careers but felt unprepared, advocating for more formal training [37]. In India, students showed interest in AI but worried about losing empathy due to overreliance on technology [34]. Similarly, UK students recognized AI's potential in radiology but feared it might limit career opportunities [36]. Arab students, despite limited exposure to AI, supported its inclusion in curricula, especially in radiology [33]. These varied perceptions highlight global recognition of AI's impact and the need for tailored educational approaches.

AI applications and chatbots in teaching and learning in medical education

Twelve of the 34 articles reviewed highlight the usefulness of AI in various areas of medical education, such as plagiarism detection, clinical simulations and homework support [38–40]. In addition, different authors mention that AI improves self-learning [41, 42] and interdisciplinary teaching, although it faces challenges in exam standardization [43] and requires human supervision to ensure accuracy [44, 45].

Numerous studies have analyzed the advantages of using chatbots such as ChatGPT in medical education [42, 43]. An innovative example of their application is described in the Canadian Medical Education Journal, where a medical data labeling program was implemented on lung ultrasound images. In this context, students were actively involved, which opened new possibilities for integrating AI into medical education [46].

Most studies highlight the need to train students in the effective and consistent use of AI. A key advantage of AI in medical education, particularly in the study of anatomy, is its ability to overcome limitations of the traditional approach, such as the scarcity of cadavers for dissection and the risks associated with handling toxic chemicals during embalming and dissection procedures [47].

Ethical considerations and challenges

Six reviewed articles address the ethical considerations surrounding the implementation of AI in medical education [29, 39, 44, 48, 49]. These studies agree on the importance of generating awareness in medical students about

the lack of human essence in AI, highlighting the need to reinforce empathy and warmth in dealing with patients.

In addition, two authors point out that AI often introduces information bias, which makes it necessary to counteract this problem by thoroughly reviewing the data that students acquire from these technologies. They also suggest that traditional teaching should not be discontinued until this shortcoming is significantly mitigated [29, 48].

AI in assessment and feedback

From the available evidence, it was observed that 5 of the papers found sought to identify the role of AI in medical education assessment and assignment [33, 47, 50–52]. Among the advantages mentioned in basic medical science education, AI can be applied by giving feedback on anatomy practice, with simulated clinical anatomy sessions, creating videos for dissections and practices, and allowing online work [47]. AI via Machine Learning (ML) and Deep Learning (DL) can address the inherent limitations of traditional education methods to build a personalized, effective and fair educational landscape, functioning as a trainer or coach with predictive analytics [52]. On the other hand, the construction of a self-learning system mediated by artificial intelligence, allowed undergraduate students to access a friendly knowledge system, with a high degree of satisfaction and good performance in tests of quality and retention of information [51].

In addition, one of the most outstanding aspects lies in the capacity offered by AI to effectively address plagiarism based on a personalized and relevant educational model. Other challenges to be considered when discussing this aspect are privacy, transparency and the development of propagation bias [33, 47, 52].

The future of AI in medical education

We pooled the information available from 3 articles that provide a glimpse into the future of artificial intelligence in medical education [25, 34, 53]. It is interesting to note that there is so much evidence regarding the intervention of these digital systems in medical education that it is practically impossible for the human mind to summarize [25]. It is stated that to ensure the success of AI in medical education, it is crucial to foster interdisciplinary collaboration and increase investment in education and training [34]. In this respect, the integration of AI in education has not yet been described in a way that allows us to clearly glimpse its impact, although it has been shown that when the learner has to talk to an Intelligent Tutoring System (ITS), his understanding and handling of the subject increases, which allows us to imagine where the educational models will migrate to [53].

In addition, it outlines several challenges that must be overcome to achieve the implementation of artificial intelligence in medical education such as the complete overhaul of medical school curricula to provide a focus on the effective use of AI in medicine and the construction of a robust ethical framework to ensure patient safety, privacy and autonomy, promoting equity and inclusivity [25, 34].

Discussion

This scoping review provides an comprehensive overview of the integration of artificial intelligence in UME, highlighting the diversity of approaches, ethical considerations, and global discrepancies. The review also identifies critical research gaps and limitations while proposing recommendations for enhancing AI curricula to meet the evolving needs of healthcare.

Diversity in AI curriculum content and delivery

The studies reviewed demonstrated considerable variability in AI curriculum development and delivery. Some focused on foundational AI concepts, such as machine learning and deep learning, introduced during pre-clinical years, while others employed a staged approach, integrating these concepts in clinical contexts [41, 45–47, 54]. This heterogeneity underscores the lack of a standardized framework, complicating the creation of cohesive and comprehensive AI education models that align with modern healthcare demands. As highlighted in the results described in 3.2, collaborative learning, teamwork skills, interdisciplinary abilities, and basic digital skills are emerging as transversal competencies. These competencies provide curricular support for integrating AI as a tool rather than as a subject of study itself, facilitating its adoption across diverse educational settings without necessarily establishing it as standalone content. Establishing consensus on essential AI skills and competencies is necessary for ensuring consistency and effectiveness in AI integration across UME programs.

Ethical education and digital competence

Ethical training and digital literacy emerged as fundamental components in AI curricula. Many studies stressed the importance of preparing students to navigate ethical challenges related to AI, such as maintaining patient confidentiality, recognizing algorithmic biases, and ensuring informed consent [28–32]. However, despite this consensus, the literature lacks comprehensive strategies and standardized curricula to systematically teach these competencies. This gap indicates a need for further curriculum development to incorporate structured and evidence-based approaches to ethical education.

Existing studies have demonstrated that AI applications, such as Intelligent Tutoring Systems and virtual simulations, significantly enhance learning outcomes by providing adaptive, personalized training and reducing geographical barriers to education [23, 24, 53]. These tools have been shown to improve self-directed learning and critical thinking skills, essential for navigating AI-integrated clinical environments [24, 25]. Early research on learning outcomes also highlights that a staged integration of foundational AI concepts, followed by their application in clinical settings, fosters better knowledge retention and practical skill development [29, 32, 51].

Faculty readiness is a critical factor in the successful integration of AI into medical education. Many medical educators lack formal training in AI, which can hinder effective curriculum implementation. Providing faculty development programs, workshops, and interdisciplinary collaborations with AI specialists can bridge this gap. Furthermore, AI literacy training should focus not only on technical aspects but also on ethical considerations, clinical applications, and teaching strategies. Without adequate faculty support, AI education risks being inconsistently implemented, leaving students without the necessary guidance to critically engage with AI-driven tools in their future clinical practice.

By addressing these gaps through standardized curricula, medical education can better prepare future physicians to responsibly and effectively use AI technologies while upholding the ethical principles critical to patient care.

Pedagogical approaches and experiential learning

A variety of pedagogical methods were proposed across the studies, including lectures, e-learning modules, collaborative learning platforms, and hands-on experiences with AI tools [46, 47, 50, 54–56]. Experiential learning was consistently recommended as a critical component for effective AI training; however, the lack of robust evaluations and evidence-based frameworks limits its understanding of the most effective approaches. AI, as a tool for teaching and learning, can be used interactively, allowing students to learn from it without necessarily being the object of study itself. Further research is needed to identify optimal pedagogical strategies and establish structured evaluations to assess student outcomes comprehensively.

The lack of standardization in AI curricula across medical schools presents a major challenge to ensuring consistency in AI education. While some institutions have introduced AI as a standalone subject, others integrate it into existing courses with varying levels of depth. A possible solution is to develop a core competency framework outlining the essential AI-related skills that all medical students should acquire. Collaborative efforts between medical education governing bodies, AI experts, and curriculum developers could help establish standardized AI learning objectives. Additionally, accreditation bodies could play a role in encouraging AI integration by setting minimum competency requirements for medical graduates, ensuring that all students, regardless of institution, receive foundational training in AI applications relevant to clinical practice.

Global discrepancies in AI integration and student perceptions

The geographical diversity of the studies highlights significant global discrepancies in AI integration and student perceptions. While North American and European studies emphasized the need for formal, structured AI training to enhance clinical decision-making, studies from regions like Nigeria and India expressed concerns about the dehumanization of healthcare and the risk of technology overreliance [33–37]. Additionally, North American and European models often integrated interdisciplinary approaches, fostering collaboration between medical and technological disciplines to enhance critical thinking and teamwork skills [23–27]. In contrast, studies in regions like Nigeria highlighted a limited exposure to interdisciplinary applications, focusing more on standalone AI tools as solutions to immediate challenges [33–37]. These regional differences suggest that, although there is a shared acknowledgment of AI's importance, curricula must be tailored to cultural and institutional contexts to ensure their relevance and effectiveness globally.

Through the strategic use of AI, countries in development can overcome some challenges and improve the quality and reach of medical training. Among the key approaches, AI enables access to personalized learning materials, using low-cost applications to tailor educational resources to individual levels of knowledge. AI also enables the adaptation of content to local languages and cultural contexts, helping learners better understand information. In addition, chatbots and virtual tutors can offer constant support, resolving doubts and providing feedback in real time, also facilitating virtual clinical simulations and practices, training students in complex situations without the need for physical facilities and at lower cost, while image recognition algorithms support learning in assisted diagnosis, especially useful in areas with few specialists [23, 32, 33]. Despite its advantages, the use of AI in low-resource settings faces challenges, such as limited technological infrastructure, lack of connectivity in rural areas, and the need for technology training for teachers and students. However, if implemented in an adaptable, accessible and sustainable manner, AI could

have a positive and lasting impact on medical education in these communities.

These findings underscore the necessity of aligning AI education frameworks with regional healthcare priorities and cultural values. Tailoring interdisciplinary models to fit local contexts ensures that AI integration addresses the diverse needs of medical education systems globally, enhancing both its applicability and impact.

Ethical challenges and opportunities of AI in transforming medical education

The ethical implications of AI integration in medical education are critical for ensuring that the use of AI enhances learning without compromising the human values inherent to healthcare practice. AI lacks the capacity for empathy and moral judgment, which are essential characteristics of health professionals [29]. This raises concerns about the potential impact of increased AI reliance on the development of interpersonal skills and the ability to respond compassionately to patients' emotional and psychological needs [55]. As AI tools become more prominent, bioethics education must adapt, ensuring that AI is viewed as a complementary tool while emphasizing the healthcare professional's responsibility in decision-making [48]. Additionally, equity and access are ethical considerations that must be addressed. While AI has the potential to improve medical education globally, unequal access could amplify existing disparities, disadvantaging students and professionals in resource-limited settings [44]. Concerns about privacy and data security are also significant, particularly when using AI tools like chatbots that handle sensitive patient information [40]. Developing strict regulations and ethical frameworks is essential to protect confidentiality and prevent legal issues.

Educational innovation: the impact of AI on teaching and learning in medicine

AI is revolutionizing medical education by providing innovative tools that enhance both teaching and learning [38, 55, 56]. On the instructional side, AI applications are used for plagiarism detection, curriculum development, automated feedback, and clinical simulations [47]. For students, AI serves as a resource for addressing questions, practicing clinical cases in safe environments, and receiving real-time feedback. Perhaps the most promising focus in medical education is precision medical education, similar to precision medicine, which allows for personalized competency development in students. AI, with its foundational capabilities in analytics, supports this approach, enabling tailored learning experiences [46]. In this regard, and contrasting with geographical variability, there is a highlighted need for standardization and adaptation of foundational skills necessary for AI adoption, continual development, and innovation within medical education. These tools not only promote interactive and efficient education but also prepare future physicians to navigate technological changes and the globalized healthcare landscape.

Systemic and regional barriers to AI curriculum adoption

Despite AI's transformative potential in medical education, its integration remains uneven across regions, particularly in low-resource environments. Systemic barriers—ranging from infrastructure limitations to faculty readiness and regulatory gaps—vary significantly depending on local economic and technological contexts.

Financial and infrastructure constraints

Medical schools in low- and middle-income countries (LMICs) often lack access to AI-driven educational tools, including high-speed internet, cloud computing, and AI-based simulation platforms. Institutions in high-income countries, by contrast, benefit from substantial investments in AI-enhanced learning environments. AI implementation in LMICs is hindered by limited digital infrastructure and the high costs of AI integration, restricting access to advanced AI-powered educational tools and training programs [57]. Cloud computing has been proposed as a potential solution, allowing resource-limited institutions to access AI tools without the need for significant in-house infrastructure investments [57].

Faculty training deficits

Faculty AI literacy varies across regions, with educators in resource-limited settings often having limited access to AI training programs. Without structured faculty development, AI integration remains inconsistent. One of the major barriers identified is the scarcity of AI-related instructional resources tailored to LMICs, which restricts faculty engagement with AI-based medical education [58]. Expanding access to faculty training programs and leveraging online AI education platforms could help mitigate these barriers.

Ethical and regulatory uncertainty

Many institutions face unclear policies regarding AI in medical education, particularly concerning data privacy, AI-assisted assessments, and ethical guidelines. In LMICs, AI adoption in healthcare is further challenged by a lack of regulatory frameworks ensuring AI tools align with local health systems and ethical standards, leading to inconsistencies in implementation [57]. Additionally, the limited availability of high-quality training datasets specific to LMICs creates further challenges for AI development and deployment, as most AI models are

trained on data from high-income countries, potentially introducing bias and reducing local applicability [58].

Study limitations and research justification

Limitations in methodological rigor and generalizability

Many studies in this review exhibit limitations in methodological rigor, including the absence of standardized evaluation metrics and reliance on self-reported data from small, non-representative samples, which affects the strength and generalizability of findings. Additionally, the scarcity of longitudinal studies impedes a comprehensive understanding of AI training's long-term impact on clinical decision-making and skill transfer. Addressing these methodological limitations through multi-institutional studies with robust designs is essential for creating reliable, scalable models for AI education.

Research gaps in low-resource contexts

A critical gap identified is the limited exploration of AI integration in medical education within low-resource settings. Investigating how AI curricula can be adapted to regions with limited technological infrastructure, while still fostering essential competencies, presents a valuable research opportunity. Future studies should prioritize this area to develop adaptable and accessible AI education models that promote equitable training standards globally.

Need for standardized pedagogical approaches

The lack of standardized pedagogical approaches in AI curricula hinders the development of cohesive training frameworks. Further research is required to examine how standardized curricula influence clinical skills and decision-making. Multi-institutional, diverse studies can address this gap, providing insights into the effectiveness of different educational models and informing evidence-based best practices for AI education in medical contexts.

This scoping review acknowledges potential biases in the study selection and analysis processes. Limiting the inclusion criteria to studies published in English and Spanish may have excluded relevant research in other languages, reducing the diversity of perspectives. Similarly, the reliance on specific databases like PubMed, Scopus, and BIREME might have introduced selection bias by underrepresenting certain regions or less-accessible research.

Potential bias in study selection and analysis

This review excluded conference abstracts and grey literature, which may contain early-stage findings, pilot programs, and evolving technological advancements in AI applications for medical education. While these sources can provide valuable insights, they often lack peer review, standardized methodologies, and comprehensive data, making it challenging to assess their rigor and reproducibility. Additionally, the thematic analysis method, while systematic, involves subjective interpretation, which may have unintentionally emphasized certain findings over others. The iterative refinement of inclusion criteria during the study selection process may also have influenced the final set of included studies, potentially impacting the comprehensiveness of the results.

These limitations highlight the need for caution when generalizing findings, particularly for underrepresented regions and contexts. Future research should consider expanding the linguistic and geographical scope, incorporating select grey literature, and employing independent validation methods to enhance the reliability and applicability of results.

Recommendations for future research and practice

Create a standardized, consensus-based AI curriculum with defined competencies

Developing a standardized AI curriculum requires actionable steps to ensure its effective implementation. Curriculum developers should organize interdisciplinary workshops involving educators, AI experts, and healthcare professionals to identify core competencies. To achieve this, working groups should be established, bringing together medical educators, AI specialists, and accreditation bodies to define the core AI competencies required for medical students. Using the Delphi method can help reach consensus on minimum AI-related learning objectives, ensuring alignment with accreditation standards. Additionally, pilot programs should be introduced across multiple institutions, with data collection on student performance to evaluate effectiveness before large-scale implementation.

Embed ethical training as a core component alongside practical skills development

Embedding ethical training into AI-related courses can be achieved by designing case-based learning modules that address real-world challenges such as algorithmic bias, patient privacy, and decision accountability. Interdisciplinary collaborations between medical faculties and bioethics departments should be established to develop structured ethical AI coursework. Furthermore, mandatory assessments should be incorporated to evaluate students' ability to navigate ethical AI applications in clinical practice. These measures will help ensure that students not only understand AI's technical capabilities but also develop the ethical reasoning necessary to apply AI responsibly in healthcare.

Implement experiential learning modules for applied AI skills

Experiential learning should focus on simulation-based activities where students engage with AI tools like diagnostic algorithms and clinical decision support systems. Introducing AI-powered clinical simulations will allow students to interact with AI-driven decision-support tools in a controlled environment, helping them understand their potential and limitations. Additionally, AI-focused problem-based learning (PBL) sessions should be incorporated, where students analyze real medical cases using AI-generated insights. Partnering with health technology companies will provide students with hands-on exposure to AI applications in medical practice, further reinforcing their practical skills.

Conduct research and evaluation to validate curriculum impact on clinical competencies

Validating the impact of AI curricula involves implementing pilot programs to test their effectiveness. Institutions should collect baseline data and track outcomes such as clinical competency, decision-making skills, and patient care quality. Longitudinal studies should be conducted to assess the long-term impact of AI education on medical students'diagnostic accuracy and clinical reasoning. Standardized evaluation metrics should be developed to compare AI curricula across different institutions, ensuring a comprehensive understanding of best practices. Findings from these studies should be disseminated through international AI in medical education conferences to promote continuous improvements and knowledge sharing.

Adapt curriculum to regional needs and resource availability

Adapting AI curricula to regional contexts requires conducting needs assessments to identify barriers, such as limited infrastructure or access to AI tools. Flexible curriculum models should be developed, offering both high-tech AI learning tools and low-resource alternatives, such as AI case studies and offline learning modules for regions with limited digital access. Additionally, partnerships with governmental and non-governmental organizations should be encouraged to provide funding and support for AI curriculum implementation, ensuring inclusivity and relevance across diverse educational settings.

Conclusions

This scoping review underscores the critical need for standardized curricula to integrate artificial intelligence effectively into undergraduate medical education. While diverse approaches exist across regions, a cohesive framework is essential to align AI competencies with the demands of modern healthcare. Standardizing AI education will ensure that future physicians are equipped with both technical skills and ethical insight, emphasizing the importance of interdisciplinary training that merges digital competence with patient-centered, ethical practices.

As AI reshapes medical practice, medical education must adapt to foster a balanced approach that includes ethical considerations alongside technological proficiency. Establishing a structured, evidence-based AI curriculum will prepare students not only for clinical applications but also for navigating the broader ethical landscape, ensuring that they can harness AI's potential responsibly to improve healthcare quality while maintaining the human aspects of the patient-physician relationship.

Appendix

Declaration of generative AI and AI-assisted technologies in the writing process

The authors used the o1 model preview developed by OpenAI during October 2024 and Microsoft Copilot software to improve the readability and language of the manuscript. This tool was utilized specifically for language editing, including grammar correction and sentence restructuring. The AI model was applied with their oversight and control, and they carefully reviewed and edited the results. The authors take full responsibility for the integrity and scientific accuracy of the content.

AI Implications in Medical Education	Articles	Subthemes
Impact of AI on Medical Education	[23–27]	Interdisciplinary AI Education in Medical Curricula · Promote interdisciplinary learning by integrating AI concepts into medical education, fostering critical thinking and collaboration across diverse fields of study, including medicine and natural sciences [27] Balancing Technological and Human Aspects of Medicine · AI must be balanced with human-centered, hands-on medical practice to avoid reducing patient care to algorithmic decision-making [26] Redesigning Medical Curricula for AI Integration · Medical education must shift from information acquisition to knowledge management, with a focus on using AI for precision medicine and enhancing physician-patient communication [3] AI-Enhanced Learning and Training Efficiency · AI-integrated models could accelerate medical knowledge acquisition and streamline training, making education more efficient and accessible [24] AI's Role in Evolving Medical Education Frameworks · AI-driven changes require a shift in medical education, focusing on digital literacy and collaboration with patients to ensure ethical and effective use of AI [23]

AI Implications in Medical Education	Articles	Subthemes
AI in Curriculum Development	[28–32]	Incorporating AI Competencies into Medical Curricula · AI competencies should become an integral part of the mandatory medical school curriculum to equip future physicians with the necessary skills to interact with AI systems and make informed decisions [28] Staged Model for AI Integration in Medical Education · A staged approach to AI education is recommended, with students learning AI fundamentals in pre-clinical years and applying AI-based clinical applications in later clinical years [29] Ethical Foundations for AI Integration in Medical Education · AI education in medical curricula must prioritize ethical considerations, ensuring that future physicians understand the implications of AI, including patient confidentiality, algorithmic biases, and informed consent [30] Ethical and Purposeful Use of AI in Medical Education · Medical students must be trained to use health data and AI technologies in alignment with ethical and legal standards, ensuring the appropriate application of AI in clinical practice and safeguarding patient records for AI processing [31] Preparing Medical Students for AI Integration in Medicine · Medical students need structured education on AI to navigate the evolving healthcare landscape, ensuring they understand AI's role while maintaining ethical standards and the humanistic aspects of patient care [32]
Perceptions and Attitudes towards AI	[33–37]	Exploring AI in Medical Education in Nigeria [45] · Medical students in Nigeria show both excitement and apprehension towards AI, with a significant number fearing that AI could diminish physicians' skills and dehumanize healthcare [35] AI in Canadian Medical Education · Canadian medical students believe AI will be integral to their careers, yet a majority feel that AI education is insufficient, highlighting the need for formal AI training in the curriculum [37] AI Acceptance in India's Medical Education · While Indian medical students demonstrate strong interest in AI integration, they express concerns about overreliance on AI and the risk of losing empathy in patient care [34] Perceptions of AI in UK Medical Education · UK medical students recognize the importance of AI in healthcare but feel inadequately prepared, especially with respect to radiology, where they fear AI may reduce career opportunities [36] AI in Medical Education across Arab Countries · Arab medical students, despite their limited AI training, acknowledge the potential of AI to revolutionize radiology and advocate for its inclusion in medical curricula [33]
AI Applications in Teaching and Learning	[46, 47, 50, 54–56]	Teaching, Learning and Assessing Anatomy with Artificial Intelligence: The Road to a Better Future · AI can be used for plagiarism detection, curriculum design, feedback on practice, simulated clinical sessions, creating dissection videos, and supporting online assignments [47] Artificial intelligence and medical education: application in classroom instruction and student assessment using a pharmacology & therapeutics case study · AI significantly enhances medical education through improved self-study support, integrated interdisciplinary learning, and relevant aspect identification, despite challenges in multiple-choice question construction and standardization [54] Difficulties of artificial intelligence in medical education · The formality and rigidity of AI models can make it difficult to teach anatomical "uncertainty," so it is recommended that the anatomy education community collaborate with developers to integrate this variability into AI tools [56] · AI generates adequate test items but requires human review to ensure accuracy and avoid errors. Limitations include the possibility of memorizing answers and extracting data from unauthenticated sources. It is suggested that teaching staff be trained in the use of AI and that the security of these tools be further improved [55] · Using ChatGPT to create simulated clinical cases has been successful in diversifying topics but has been presented with errors in accuracy and cultural and medical detail [50] Using artificial intelligence as an innovative learning strategy · An innovative program allowed medical students to participate in labeling lung ultrasound image data, improving understanding of AI and medicine [50] · The use of AI could improve self-assessment, data analysis, and hands-on training with clinical simulations to automate processes, reduce risks and costs, and adapt to post-pandemic educational changes, incorporating advanced technology into medical education [55] · The mobile app offers personalized recommendations and functionalities such as tournaments, rankings and challenges to foster student collaboration and leadership [46]

AI Implications in Medical Education	Articles	Subthemes
Use of Chatbots and ChatGPT in Medical Education	[38–45]	Potential of AI language models in clinical decision making · ChatGPT can help formulate article outlines, paraphrase texts, and speed up literature review. However, there are challenges with verifying AI-generated sources and citations [38] Weaknesses arising from the use of chatbots in medical education · Misuse of ChatGPT can compromise academic integrity and lead to over-reliance, raising the need for policies and strategies to mitigate these risks [44] · Chatbots are underused in UK medical education due to a lack of development appropriate to student needs, lack of promotion by institutions, and students'lack of awareness of the potential benefits [45] Opportunities for integrating chatbots in clinical care, teaching and research · Chatbots can be useful in the early years of medical training, providing a safe environment for learning before direct clinical contact [41] · By providing accurate medical guidance, they reduce costs and improve patient outcomes. ChatGPT- 4 could be integrated into patient simulations and personalized learning, as well as assisting in research production [41] · The integration of tools such as ChatGPT can reduce knowledge gaps, expand differential diagnoses, question medical axioms and support decision making in acute care and complex cases [40] · ChatGPT facilitates the dissemination of popular information, can marginalize local cultures and languages, affecting cultural diversity. Furthermore, its use could open new opportunities in areas such as medical AI and information management [39] · Chatbots could be used as patient simulators, review tools or to standardize exams, thus improving self-learning and reducing tutor intervention [38]
Ethical Considerations and Challenges	[29, 38, 44, 48, 49]	Ethical perceptions surrounding the use of artificial intelligence in medical education · The ethical management of AI is crucial to ensure its responsible use and equitable distribution of benefits, as access to the advantages of AI is not uniformly available [49] · There are many ethical and legal obstacles surrounding the implementation of AI in healthcare, an example of this is the negative perception of AI due to its lack of human essence [38] · It is necessary to critically and ethically evaluate the use of artificial intelligence, despite the convenience of obtaining easily generated information [44] · Awareness of the misinformation generated by AI about biomedical knowledge and the pathophysiology of diseases must be generated to avoid its use [29, 48]
AI in Assessment and Feedback	[47, 50–52]	Anatomy Revolution with AI · AI revolutionizes anatomy education through 3D virtual reality, aiding in curriculum design, feedback, and online learning, though logistical considerations are essential [47] AI in Pharmacology Education · AI supports medical education by enhancing self-study, offering an integrated interdisciplinary approach, and facilitating key learning aspects. However, it faces challenges with multiple-choice question construction and standardization [50] Personalized Education with AI · Precision education, driven by AI, offers personalized and effective educational experiences while addressing traditional limitations, though it must navigate challenges in transparency, privacy, and bias propagation [52] MEKAS System in Otorhinolaryngology · The MEKAS system significantly enhances self-learning in otorhinolaryngology, validated by substantial improvement in results and high satisfaction [51]
The Future of AI in Medical Education	[25, 48, 53]	Curriculum Redesign in the AI Era · A complete overhaul of medical school curricula is essential to focus on the effective use of AI in medicine [25] Ethical Framework for AI Education · Establishing a robust ethical framework is vital for ensuring safety, privacy, and equity in the integration of AI in healthcare [48] Professional Development with AI. · Evaluating and promoting AI in healthcare education can significantly enhance learners'comprehension and skills [53]

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Authors' contributions
All authors contributed to the study as follows: DJ and EHR were responsible for conceptualization. DJ, JP, and LC developed the methodology and managed the software. Validation was carried out by EHR, ART, and CJ. Formal analysis was performed by DJ, while investigation involved DJ, EHR, ART, CJ, JP, and LC. Resources were provided by EHR, ART, and CJ, and data curation was handled by DJ and EHR. DJ, EHR, JP, and LC contributed to the original draft, and DJ, EHR, CJ, and ART participated in the review and editing process. Visualization of the findings was managed by DJ, EHR, CJ, and ART. Supervision was provided by EHR, with project administration led by DJ and EHR. Funding acquisition was obtained by EHR, ART, and CJ.

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Data availability
All data generated or analysed during this study are included in this published article.

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Competing interests
The authors declare no competing interests.

Author details
[1]Department of Family Medicine and Public Health, Facultad de Medicina, Universidad de La Sabana, Campus del Puente del Común, Km. 7, Autopista Norte de Bogotá, Chía, Cundinamarca, Colombia. [2]Facultad de Medicina, Universidad de La Sabana, Campus del Puente del Común, Km. 7, Autopista Norte de Bogotá, Chía, Cundinamarca, Colombia. [3]Department of Psychiatry and Mental Health, Facultad de Medicina, Universidad de La Sabana, Campus del Puente del Común, Km. 7, Autopista Norte de Bogotá, Chía, Cundinamarca, Colombia.

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References

1. World Health Organization (WHO). WHO guideline: recommendations on digital interventions for health system strengthening: evidence and recommendations. [Internet]. Geneva: World Health Organization; 2019. Available from: https://www.who.int/publications/i/item/9789241550505.
2. da Fonseca MH, Kovaleski F, Picinin CT, Pedroso B, Rubbo P. E-health practices and technologies: a systematic review from 2014 to 2019. Healthcare (Basel). 2021;9(1192):1–32.
3. Whitelaw S, Mamas MA, Topol E, Van Spall HGC. Applications of digital technology in COVID-19 pandemic planning and response. Lancet Digital Health. 2020;2:e435–40.
4. Blumenthal D, Tavenner M. The, "Meaningful Use" regulation for electronic health records. N Eng J Med. 2010;363(6):501–4.
5. Dhaliwal JK, Hall TD, Larue JL, Maynard SE, Pierre PE, Bransby KA. Expansion of telehealth in primary care during the COVID-19 pandemic: Benefits and barriers. J Am Assoc Nurse Pract. 2022;34(2):224–9.
6. Dorsey ER, Topol EJ. Telemedicine 2020 and the next decade. Lancet. 2020;395(10227):859.
7. Dlugatch R, Georgieva A, Kerasidou A. AI-driven decision support systems and epistemic reliance: a qualitative study on obstetricians' and midwives' perspectives on integrating AI-driven CTG into clinical decision making. BMC Med Ethics. 2024;25(1):6.
8. Huang Z, George MM, Tan YR, Natarajan K, Devasagayam E, Tay E, et al. Are physicians ready for precision antibiotic prescribing? A qualitative analysis of the acceptance of artificial intelligence-enabled clinical decision support systems in India and Singapore. J Glob Antimicrob Resist. 2023;35:76–85.
9. Bekbolatova M, Mayer J, Ong CW, Toma M. Transformative potential of AI in healthcare: definitions, applications, and navigating the ethical landscape and public perspectives. Healthcare (Switzerland). 2024;12:125.
10. Khalifa M, Albadawy M. Artificial Intelligence for Clinical Prediction: Exploring Key Domains and Essential Functions. Comput Methods Programs Biomed Update. 2024;5(100148):1–11.
11. Davenport T, Kalakota R. The potential for artificial intelligence in healthcare. Future Healthc J. 2019;6(2):94–8.
12. Alowais SA, Alghamdi SS, Alsuhebany N, Alqahtani T, Alshaya AI, Almohareb SN, et al. Revolutionizing healthcare: the role of artificial intelligence in clinical practice. BMC Med Educ. 2023;23:689.
13. Organización Mundial de la Salud. Ética Y Gobernanza De La Inteligencia Artificial En El Ámbito De La Salud. World Health Organization. 2021.
14. Gordon M, Daniel M, Ajiboye A, Uraiby H, Xu NY, Bartlett R, et al. A scoping review of artificial intelligence in medical education: BEME guide no. 84. Med Teach. 2024;46:446–70.
15. Narayanan S, Ramakrishnan R, Durairaj E, Das A. Artificial intelligence revolutionizing the field of medical education. Cureus. 2023;15(11):1–9.
16. Lee J, Wu AS, Li D, Kulasegaram KM. Artificial Intelligence in Undergraduate Medical Education: A Scoping Review. Acad Med. 2021;96(11S):S62–S70.
17. Walter Y. Embracing the future of Artificial Intelligence in the classroom: the relevance of AI literacy, prompt engineering, and critical thinking in modern education. Int J Educ Technol Higher Educ. 2024;21(15):1–29.
18. Nordin MN Bin, Maidin SS, Rajoo M, Mahmod M, Jani WNFA, Yusoh MP, et al. International Frameworks For 21st century competences: comparative education. Res Militaris. 2022;12(2):7332–44.
19. Arksey H, O'Malley L. Scoping studies: Towards a methodological framework. Int J Soc Res Methodol. 2005;8(1):19–32.
20. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. Implement Sci. 2010;5(1):69.
21. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018;169:467–73.
22. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. Syst Rev. 2016;5(1):210.
23. Rampton V, Mittelman M, Goldhahn J. Implications of artificial intelligence for medical education. Lancet Digit Health. 2020;2:e111–2.
24. Xu Y, Jiang Z, Ting DSW, Kow AWC, Bello F, Car J, et al. Medical education and physician training in the era of artificial intelligence. Singapore Med J. 2024;65:159–66.
25. Wartman SA, Combs CD. Reimagining medical education in the age of AI. AMA J Ethics. 2019;21(2):E146-152.
26. van der Niet AG, Bleakley A. Where medical education meets artificial intelligence: 'Does technology care?' Med Educ. 2021;55(1):30–6.
27. Lang J, Repp H. Artificial intelligence in medical education and the meaning of interaction with natural intelligence - an interdisciplinary approach. GMS J Med Educ. 2020;37(6):Doc59.
28. Mosch L, Agha-Mir-Salim L, Sarica MM, Balzer F, Poncette AS. Artificial Intelligence in Undergraduate Medical Education. Stud Health Technol Inform. 2022;294:821–2.
29. Ngo B, Nguyen D, Vansonnenberg E. The cases for and against artificial intelligence in the medical school curriculum. Radiol Artif Intell. 2022;4(5):e220074.
30. Pregowska A, Perkins M. Artificial intelligence in medical education: typologies and ethical approaches. Ethics Bioethics Sciendo. 2024;14(1–2):96–113.
31. Çalışkan SA, Demir K, Karaca O. Artificial intelligence in medical education curriculum: an e-Delphi study for competencies. PLoS One. 2022;17(7):e0271872.
32. Civaner MM, Uncu Y, Bulut F, Chalil EG, Tatli A. Artificial intelligence in medical education: a cross-sectional needs assessment. BMC Med Educ. 2022;22(1):772.
33. Allam AH, Eltewacy NK, Alabdallat YJ, Owais TA, Salman S, Ebada MA, et al. Knowledge, attitude, and perception of Arab medical students towards artificial intelligence in medicine and radiology: a multi-national cross-sectional study. Eur Radiol. 2024;34(7):1–14.
34. Sharma V, Saini U, Pareek V, Sharma L, Kumar S. Artificial Intelligence (AI) integration in medical education: a pan-India cross-sectional observation of acceptance and understanding among students. Scripta Medica (Banja Luka). 2023;54(4):343–52.
35. Oluwadiya KS, Adeoti AO, Agodirin SO, Nottidge TE, Usman MI, Gali MB, et al. Exploring artificial intelligence in the Nigerian medical educational space: An online cross-sectional study of perceptions, risks and benefits among students and lecturers from ten universities. Niger Postgrad Med J. 2023;30(4):285–92.
36. Sit C, Srinivasan R, Amlani A, Muthuswamy K, Azam A, Monzon L, et al. Attitudes and perceptions of UK medical students towards artificial intelligence and radiology: a multicentre survey. Insights Imaging. 2020;11(1):14.
37. Pucchio A, Rathagirishnan R, Caton N, Gariscsak PJ, Del Papa J, Nabhen JJ, et al. Exploration of exposure to artificial intelligence in undergraduate medical education: a Canadian cross methods study. BMC Med Educ. 2022;22(1):815.
38. Boscardin CK, Gin B, Golde PB, Hauer KE. ChatGPT and Generative Artificial Intelligence for Medical Education: Potential Impact and Opportunity. Acad Med. 2024;99(1):22–7.
39. Xie Y, Seth I, Hunter-Smith DJ, Rozen WM, Seifman MA. Investigating the impact of innovative AI chatbot on post-pandemic medical education and clinical assistance: a comprehensive analysis. ANZ J Surg. 2024;94(1–2):68–77.

40. Vignesh R, Pradeep P, Balakrishnan P. A Tête-à-tête with ChatGPT on the impact of artificial intelligence in medical education. Med J Malaysia. 2023;78(4):547–9.
41. Lower K, Seth I, Lim B, Seth N. ChatGPT-4: Transforming Medical Education and Addressing Clinical Exposure Challenges in the Post-pandemic Era. Indian J Orthop. 2023;57(9):1527–44.
42. Skryd A, Lawrence K. ChatGPT as a Tool for Medical Education and Clinical Decision-Making on the Wards: Case Study. JMIR Form Res. 2024;8:e51346.
43. Xu T, Weng H, Liu F, et al. Current Status of ChatGPT Use in Medical Education: Potentials, Challenges, and Strategies. J Med Internet Res. 2024;26:e57896.
44. Gutiérrez-Cirlos C, Carrillo-Pérez DL, Bermúdez-González JL, Hidrogo-Montemayor I, Carrillo-Esper R, Sánchez-Mendiola M. ChatGPT: opportunities and risks in the fields of medical care, teaching, and research. Gac Med Mex Academia Nacional de Medicina. 2023;159:382–9.
45. Kaur A, Singh S, Chandan JS, Robbins T, Patel V. Qualitative exploration of digital chatbot use in medical education: A pilot study. Digit Health. 2021;7:20552076211038151.
46. Tschirhart J, Woolsey A, Skinner J, Ahmed K, Fleming C, Kim J, et al. Introducing medical students to deep learning through image labelling: a new approach to meet calls for greater artificial intelligence fluency among medical trainees. Can Med Educ J. 2022.
47. Abdellatif H, Al Mushaiqri M, Albalushi H, Al-Zaabi AA, Roychoudhury S, Das S. Teaching, Learning and Assessing Anatomy with Artificial Intelligence: The Road to a Better Future. Int J Environ Res Public Health. 2022;19(21):14209.
48. Knopp MI, Warm EJ, Weber D, Kelleher M, Kinnear B, Schumacher DJ, et al. AI-Enabled Medical Education: Threads of Change, Promising Futures, and Risky Realities Across Four Potential Future Worlds. JMIR Med Educ. 2023;25(9): e50373.
49. Alkhodari M, Xiong Z, Khandoker AH, Hadjileontiadis LJ, Leeson P, Lapidaire W. The role of artificial intelligence in hypertensive disorders of pregnancy: towards personalized healthcare. Expert Review of Cardiovascular Therapy. 2023;21(7):531–43.
50. Sridharan K, Sequeira RP. Artificial intelligence and medical education: application in classroom instruction and student assessment using a pharmacology & therapeutics case study. BMC Med Educ. 2024 Dec 1;24(1).
51. Su JM, Hsu SY, Fang TY, Wang PC. Developing and validating a knowledge-based AI assessment system for learning clinical core medical knowledge in otolaryngology. Comput Biol Med. 2024;1:178.
52. Turner L, Hashimoto DA, Vasisht S, Schaye V. Demystifying AI: Current State and Future Role in Medical Education Assessment. Acad Med. 2024;99(4):S42–7.
53. Randhawa GK, Jackson M. The role of artificial intelligence in learning and professional development for healthcare professionals. Healthc Manage Forum. 2020;33(1):19–24.
54. Bakkum MJ, Hartjes MG, Piët JD, Donker EM, Likic R, Sanz E, et al. Using artificial intelligence to create diverse and inclusive medical case vignettes for education. Br J Clin Pharmacol. 2024;90(3):640–8.
55. Lazarus MD, Truong M, Douglas P, Selwyn N. Artificial intelligence and clinical anatomical education: promises and perils. Anat Sci Educ. 2024;17(2):249–62.
56. Castellano MS, Contreras-McKay I, Neyem A, Farfán E, Inzunza O, Ottone NE, et al. Empowering human anatomy education through gamification and artificial intelligence: an innovative approach to knowledge appropriation. Clin Anat. 2024;37(1):12–24.
57. Wahl B, Cossy-Gantner A, Germann S, Schwalbe NR. Artificial intelligence (AI) and global health: how can AI contribute to health in resource-poor settings?. BMJ Glob Health. 2018;3(4):e000798.
58. Ciecierski-Holmes T, Singh R, Axt M, Brenner S, Barteit S. Artificial intelligence for strengthening healthcare systems in low- and middle-income countries: a systematic scoping review. NPJ Digit Med. 2022;5(1):162.

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