SCOPING REVIEW

Artificial Intelligence in Anatomy Education

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ABSTRACT

Background: Artificial intelligence (AI) refers to machines capable of performing human tasks and exhibiting intelligent behavior. The application of AI in medical education has increased significantly, especially during the COVID-19 pandemic, as remote teaching became widespread across all medical disciplines, including anatomy. **Objective:** This narrative review aimed to explore the potential use of AI in anatomy education and to identify any associated weaknesses or threats related to its integration. **Material and Method:** A systematic literature search was conducted using PubMed and Embase (limited to the past 5 years), and Google Scholar (limited to the past 2 years), employing keywords related to "artificial intelligence" and "anatomy education". Inclusion criteria were randomized controlled trials and review articles focusing on AI tools in anatomy education, published in English and freely accessible. Exclusion criteria included abstract-only publications, non-human studies, and studies not specifically related to anatomy education. Of the 3,298 articles identified, seven met the inclusion criteria. **Result:** Seven articles fulfilled the inclusion criteria. The reviewed literature explored AI applications in anatomy education, highlighting innovations such as blended learning, automated assessments, and digital platforms. Overall, AI demonstrates potential to improve teaching effectiveness and student engagement. However, successful implementation requires strategic planning, adequate infrastructure, and a solid pedagogical framework. **Conclusion:** AI has emerged as a valuable tool in anatomy education, enhancing learning outcomes, accessibility, and instructional flexibility. Nonetheless, its integration must be carefully managed to overcome current limitations and ensure equitable, effective, and sustainable educational practices.

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Highlights

1. Review of the potential use of AI in anatomy education, including any weaknesses or threats associated with integrating AI into anatomy teaching.
2. Recommendations for incorporating AI in anatomy education within medical curricula.

BACKGROUND

Medical practice is evolving at a rapid pace. With greater access to information, the landscape of medical education is undergoing significant transformation (Silva & Nanamura, 2024). Beyond the traditional roles of students and lecturers, advanced technologies have become essential in modern education. A key driver of recent advancements in healthcare is digital technology, often referred to as the "Fourth Industrial Revolution" (4IR) (Burney & Ahmad, 2022). The integration of technology in healthcare is widely regarded as having the potential to enhance the quality of life for populations globally (Patil & Shankar, 2023).

Artificial intelligence (AI) refers to machines capable of performing tasks typically requiring human intelligence, such as perception, reasoning, learning, and communication. Over the past 25 years, AI has made tremendous progress in the field of education (Chen, et al., 2020). A study conducted by Chan & Zary, (2019) using Web of Science revealed a growing number of publications focusing on the application of AI in medical education, reflecting increased research and development interest in this area.

The COVID-19 pandemic significantly accelerated the use of AI in education, as remote teaching became a widespread necessity across medical disciplines, including anatomy (Broadbent, et al., 2023; Imran, et al., 2025). AI has since been integrated into online anatomy learning through the development of three-dimensional anatomical models, virtual dissections, gamification strategies, and the use of virtual reality (VR) and augmented reality (AR). These technologies also extend to online simulations for surgical procedures and autopsies, as well as remote exam invigilation via online proctoring systems (Wang, et al., 2024).

However, the adoption of AI has introduced challenges to traditional anatomical education frameworks. Issues have emerged in areas such as anatomical variation, clinical practice readiness, diversity, inclusion, social justice, and student support and engagement (Awad & Oueida, 2024). Cadaveric dissection remains the gold standard in anatomy education, yet its implementation is constrained by limited teacher-to-student ratios, a shortage of qualified educators, and the scarcity of cadavers (Bhattarai, et al., 2022). It is anticipated that AI and other technological innovations can enhance anatomy education without replacing cadaveric learning, but rather by complementing it as a foundational component (Abdellatif, et al., 2022).

OBJECTIVE

Given the rapid growth of AI in medical education, this scoping review aimed to explore the potential applications of AI in anatomy education, including its advantages and disadvantages. The article sought to provide conclusions and recommendations regarding the integration of AI into anatomy teaching within medical education.

MATERIAL AND METHOD

A literature search was conducted using the bibliographic databases PubMed (last 5 years), Embase (last 5 years), and Google Scholar (last 2 years). The search yielded 208 articles from PubMed using the keywords (artificial intelligence) AND (anatomy education), 1 article from Embase using the terms ‘artificial intelligence’ OR (‘artificial’ AND ‘intelligent’) AND ‘anatomy education’, and 2,880 articles from Google Scholar with keywords artificial intelligence and anatomy education.

Inclusion criteria were randomized controlled trials (RCTs) or review articles focusing on the use of AI in anatomy education, including tools such as augmented reality (AR), virtual reality (VR), mixed

reality (MR), 3D printing, web-based programs, tablet-based platforms, and gamification tools. Articles had to be written in English and available as free full text.

Exclusion criteria included articles not written in English, abstract-only publications, studies on AI in general medical education but not specifically anatomy, research involving non-human or microscopic anatomy, book sections or chapters, and expert opinion pieces. A total of seven articles met the inclusion criteria out of the 3,298 records initially retrieved.

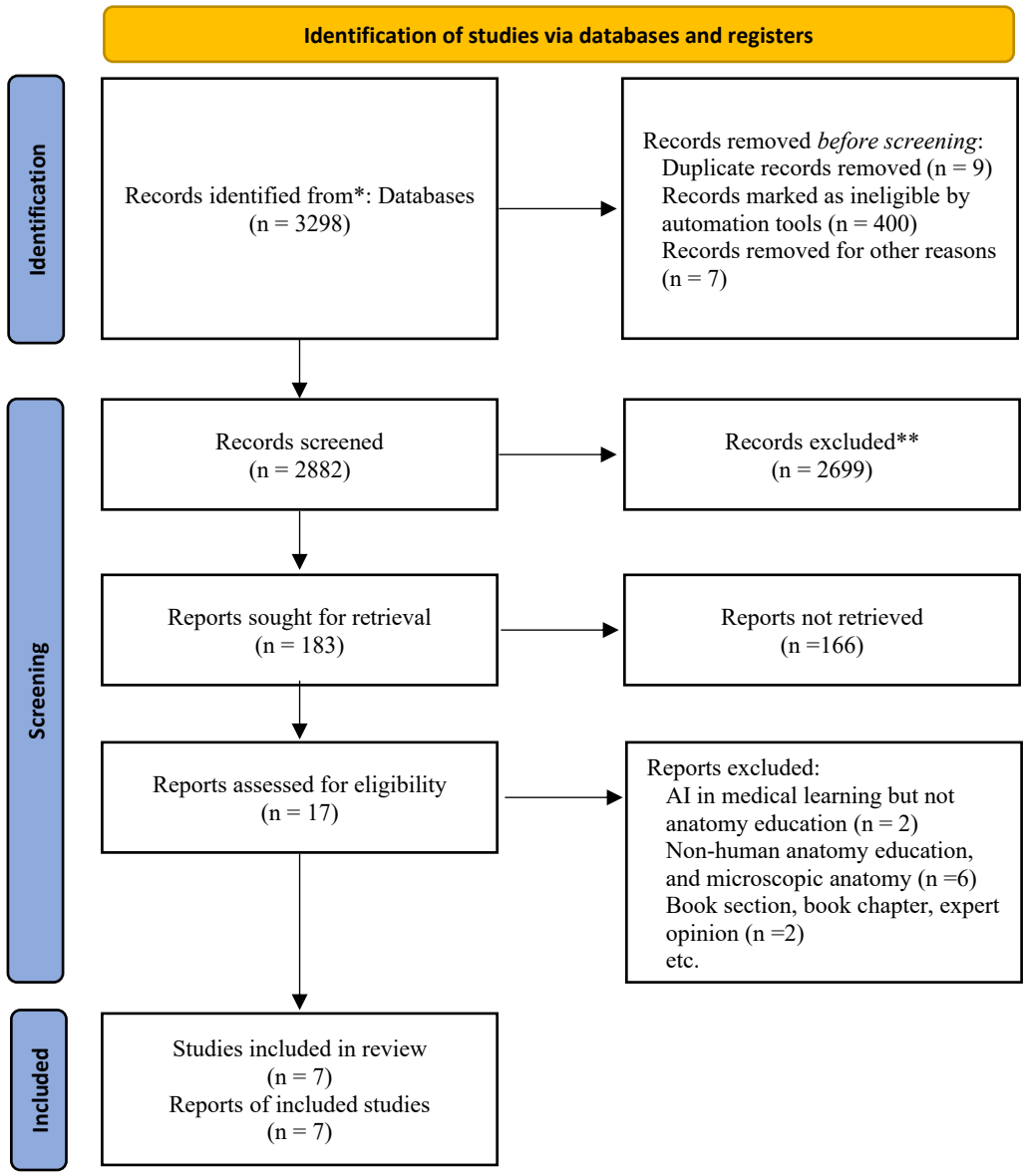

Figure 1. PRISMA ScR diagram (Tricco, et al., 2018).

RESULT

Table 1 summarizes the selected articles reviewed on the application of artificial intelligence (AI) in anatomy education. The findings highlight the promising role of AI in enhancing anatomy teaching through digital tools, automated assessments, and innovative instructional approaches. While the integration of AI offers significant benefits, such as efficiency and scalability, its effective implementation requires strategic planning, appropriate infrastructure, and a strong pedagogical framework.

Table 1. Articles included in this review on the use of AI in anatomy education.

Author	Title	Type	Result
Adnan & Xiao, (2023) doi: 10.1002/ca.23995	A scoping review on the trends of digital anatomy education	Scoping review of original article	Utilizing a combination of various digital tools and instructional techniques, known as blended learning, may represent the most effective approach for teaching anatomy.
Lazarus, et al., (2024) doi: 10.1002/ase.2221	Artificial intelligence and clinical anatomical education: Promises and perils	Narrative/scoping review	The potential benefits of AI, such as scalability, speed, consistency, and accuracy are substantial. Therefore, the anatomy education community must adopt a deliberate and strategic approach to the advancement and integration of technology in anatomy education.
Bernard, et al., (2024) doi: 10.1002/ase.2305	Automated grading of anatomical objective structured examination using decision trees: An artificial intelligent approach	Cross - sectional study	Machine learning algorithms such as Decision Trees (DT), a subset of AI-based systems, have proven to be highly effective for grading Objective Structured Practical Examinations (OSPE) and are well-suited for the development of intelligent, automated online OSPE platforms.
Patra, et al., (2022) doi: 10.1007/s00276-021-02868-6	Integration of innovative educational technologies in anatomy teaching: new normal in anatomy education	Narrative review	The adoption of online teaching methods as a temporary solution to maintain course delivery during disruptions may not lead to sustainable positive outcomes. Therefore, decision-makers must carefully evaluate how to effectively integrate both in-person and digital approaches to enhance the long-term quality of anatomy education.
Asghar, et al., (2022) doi: 10.1007/s00276-022-03020-8.	The potential scope of a humanoid robot in anatomy education: a review of a unique proposal	Narrative review	Although humanoid robots equipped with artificial intelligence have been effectively employed in primary education and language learning, their use as instructors or assistants in anatomy education remains a novel and largely untested concept.
Wickramasinghe, et al., (2022) doi: 10.2196/34687	The opportunities and challenges of digital anatomy for medical sciences: A narrative review	Narrative review	Digital anatomy holds the potential to enhance real-time clinical practice in situ, as well as teaching and learning processes across various educational levels. However, it should not be regarded merely as a simple technological advancement; rather, its implementation requires a well-defined and robust pedagogical framework.
Abdellatif, et al., (2022) doi: 10.3390/ijerph192114209	Teaching, learning, and assessing anatomy with artificial intelligent: The road to a better future	Narrative review	While AI may not replace human interactions, it has the potential to transform the teaching and understanding of anatomy. Successful implementation of AI requires adequate human resources and infrastructure, as well as continuous development to effectively accommodate diverse cultural, racial, and ethnic contexts.

DISCUSSION

Artificial intelligence (AI) encompasses methods that enable machines to replicate intelligent human behaviors, including symbolic approaches (logic and knowledge-based systems), statistical techniques (such as probabilistic methods and machine learning), and sub-symbolic paradigms (which focus on embodied intelligence, search, and optimization). These frameworks address key cognitive functions

such as perception, reasoning, knowledge representation, planning, and communication. Evaluating the effectiveness of AI in anatomy education ideally requires comparative studies against conventional teaching methods (Ahmad, et al., 2021; Chan & Zary, 2019; Kushwaha, et al., 2024).

A review by Adnan & Xiao, (2023) of four studies on digital anatomy showed increased learner satisfaction compared to traditional approaches. One study highlighted the clear advantage of enabling practical simulation. However, six studies found no significant impact on learning performance in theory-based examinations. (Bernard, et al., 2024) reported that AI-driven online OSPE (Objective Structured Practical Examination) systems utilizing Decision Trees (DT) achieved an accuracy of 94.49% in grading 54 questions, suggesting high effectiveness for automated assessment. Yet, this finding is limited by data from a single OSPE, indicating the need for validation across multiple cohorts to improve and confirm the algorithm's reliability.

Patra, et al., (2022) emphasized that integrating technology into anatomy education is crucial to enhance learning outcomes and reduce the cognitive burden posed by anatomy's extensive scope. Reliable technology access ensures students can benefit fully, and careful implementation with creative adaptations is necessary to deliver timely and effective education, especially in pandemic contexts. Virtual cadavers offer lifelike 3D anatomical visualization and low-stress environments to develop fine motor skills. Nevertheless, cadaveric dissection remains the gold standard, offering firsthand experience critical for early surgical skill development. Virtual dissection lacks practical realism, and postgraduate surgical training through cadaver practice remains unmatched. Furthermore, many educators require training to utilize AI tools effectively, while inequities in technology access create disparities in learning opportunities. Reliance solely on online atlases may also undermine student confidence and increase performance anxiety due to inadequate practical understanding of complex anatomy.

According to Asghar, et al., (2022), AI-based robotic instructors offer advantages such as speed, consistency, and fatigue-free performance. These robots can respond without distraction, potentially reducing teacher training time through onsite robot specialist support. Research suggests student interactions with robots can be as effective as peer learning, encouraging wider acceptance of robotic educators. Combining robotic teaching with anatomist involvement could enhance curriculum development and evaluation. Virtual reality (VR) simulators further assist in improving dissection skills through computer-simulated environments. However, significant limitations exist: humanoid robots lack social behaviors, empathy, and creativity inherent in human teachers. Recognition issues in speech and gesture understanding may reduce student engagement. Current AI algorithms cannot replicate empathy or scientific insight crucial for medical students. Emerging educational technologies require long development periods, are difficult to customize, and often fail to maintain student interest. Ethical concerns, particularly regarding privacy and data security, are major issues when personal information is disclosed online.

Wickramasinghe, et al., (2022) identified several benefits of AI in anatomy education: long-term cost-efficiency and low maintenance, accessibility of digital resources, adaptability, improved safety, and alignment with increased remote learning demands and growing student populations. They also noted the integration of surface and regional anatomy with virtual dissection enhances learner satisfaction and visualization of deeper structures. Combining medical imaging with gross, microscopic anatomy, physiology, and pathology in a unified platform can improve clinical reasoning, cognitive skills, memory retention, and knowledge post-intervention. It facilitates group-based learning on the same anatomical structures, unavailable through single cadavers or models, and supports patient education and surgical planning. Moreover, AI allows for flexible curriculum updates, reduces disparities, and encourages resource sharing and teamwork. However, early setup costs, hardware compatibility issues with traditional cadaver labs, ongoing upgrades, resistance from traditionalists, limited tactile feedback in virtual dissections, and a lack of learner-centered digital frameworks remain significant challenges. Currently, a standardized pedagogical framework for AI integration in anatomy education is lacking.

Abdellatif, et al., (2022) highlighted AI's potential as a teaching assistant capable of precise anatomical examination and segmentation. AI aids instructional tool creation (procurement, preparation, embalming, dissection, plastination) and assessment by not only collecting but also analyzing data, ensuring future practitioners are integrators and interpreters rather than mere data gatherers. Nonetheless, the effectiveness of AI depends on operator skill, infrastructure, and connectivity, which vary across ethnic, geographic, and racial contexts, necessitating tailored solutions.

Combining multimodal and blended learning approaches that integrate AI-based and conventional methods will further modernize anatomy education while supporting the development of competent

operative skills (Khalil, et al., 2018; Rangareddy & Nagaraj, 2022). More large-scale controlled trials are needed to directly assess the effectiveness of digital anatomy education compared to traditional methods. Future anatomy education ecosystems may include digital anatomy laboratories as integral components of comprehensive learning experiences. To fully embrace and realize the potential of digital anatomy, policy changes are essential to encourage and support its widespread adoption (Quek, 2024). Careful attention must be given to establishing appropriate standards and ensuring quality in the construction, design, and development of digital anatomy resources. Effective learning can be enhanced by addressing students' auditory and visual learning preferences, enabling AI tools to foster critical understanding and align with defined learning objectives (Ramadan, et al., 2024; Ajani, et al., 2024). While AI-based teaching materials are valuable learning aids designed for accessibility and ease of use, the learning process ultimately requires learners' intrinsic motivation and active engagement (Adnan & Xiao, 2023).

Strength and limitations

This research is a scoping review that discusses the advantages and disadvantages of using AI in medical education, with a particular focus on anatomy. A key strength of this study is its balanced overview of both the benefits and limitations of AI integration in medical education. It is anticipated that this review will offer recommendations for the optimal implementation of AI in this field. However, a limitation of the study is that it did not employ a systematic review or meta-analysis approach, due to the limited number of relevant articles available, especially those from Indonesia that directly compare AI usage with conventional teaching methods.

CONCLUSION

Advancements in AI over the past 25 years have significantly influenced education, especially medical education during the pandemic. In anatomy education, AI technologies such as AR, VR, 3D printing, and web- or tablet-based applications have enhanced both regional and general anatomy learning, as well as digital examinations. AI integration offers advantages including improved learning satisfaction through superior structure and pattern recognition, increased accessibility for remote learners, and greater flexibility for educators teaching from remote locations.

However, challenges remain in areas such as accounting for human anatomical variations, healthcare practice integration, diversity and social justice, student support, and learning efficacy. Evidence suggests that combining AI-based methods with conventional cadaveric learning yields higher post-test scores compared to cadaveric learning alone. Additionally, computer-assisted learning and 3D anatomy modalities improve learning outcomes, student satisfaction, and spatial understanding, especially for complex neuroanatomy. While AI enhances anatomy education, addressing its limitations is essential to ensure equitable, effective, and inclusive implementation in medical education.

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Conflict of Interest

All authors declare no conflicts of interest.

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Author Contribution

EF, MS, MD contributes to conception and design, analysis and interpretation of the data, critical revision of the article for important intellectual content, and collection and assembly of the data. KI. KI, HN, TN, EF contributes to drafting of the article and final approval of the article.

Data Availability
None.

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