Review Article

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The Role of AI in Shaping Medical Education: Insights from an Umbrella Review of Review Studies

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Introduction: Artificial intelligence (AI) has become integral to various fields, including medical education. This study explores AI applications in medical education through a review of relevant studies.

Methods: Using the umbrella review method, this study synthesized findings from reviews conducted between 2018 and 2024. The PRISMA framework guided a comprehensive search of databases, including Science Direct, Springer, ERIC, PubMed, and Google Scholar. After quality assessment with the CASP framework, 77 systematic review articles were selected. Data analysis employed Elo and Kyngäs's qualitative content analysis approach, supported by expert validation and researcher consensus.

Results: Six key themes of AI applications in medical education were identified: faculty, students, teaching and learning process, assessment, curriculum, and management/implementation. Management and implementation had the highest representation (26.5%), followed by teaching and learning processes (25.9%). Examples of each theme were highlighted. China produced the most articles, and three journals—International Journal of Educational Technology in Higher Education, Computers and Education: Artificial Intelligence, and Education and Information Technologies—were the leading publication venues.

Conclusion: These six themes provide a roadmap for medical education policymakers to adapt to AI advancements. Emphasizing management and executive applications, the findings predict significant changes in the future of medical education and practice. This framework can help medical universities align curricula and operations with the evolving landscape of AI in healthcare.

Keywords: Artificial intelligence; Medical education; Machine learning; Educational technology

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Introduction

Higher education systems, as dynamic subsystems of broader social structures, interact with and influence their surrounding social environments. To remain relevant and effective, these systems must adapt to technological advancements by integrating modern technologies and offering services that meet emerging social and individual needs (1). Artificial intelligence (AI) encompasses various capabilities, including natural language processing, expert systems, machine vision, speech recognition, and more. This technology can perform functions that, in many cases, surpass human activities in terms of accuracy and quality (2). In the field of medical education, the rapid advancement of technology continuously expands the scope of knowledge required for expertise in this domain. This ongoing expansion places a significant burden on professionals and creates an increasing demand for innovative approaches to learning and education (3). AI-based technologies play a crucial role in medicine by analyzing and processing vast amounts of information. Consequently, they contribute significantly to enhancing medical education processes (4, 5). Given its high potential to revolutionize medical education, the use of AI in this field has become an inevitable reality (6, 7). The utility of AI technologies, such as ChatGPT, in education and research is nuanced, offering both significant advantages and potential drawbacks, while posing unique challenges and opportunities (8, 9).

This duality underscores the need for careful consideration as we navigate the integration of AI into medical education. Some of the relevant challenges include concerns over privacy, data confidentiality, lack of informed patient consent for using personal data, insufficient oversight in treatment decision-making, and potential risks to patient health (10-12). Conversely, the opportunities created by AI in medical education are noteworthy. These include decision support in diagnosis, workflow management, personalized learning, simulation-based education, and individualized feedback based on performance (13-15). Figure 1 provides an overview of the opportunities and challenges of AI in medical education.

This study offers significant insights to medical educators and scholars by providing a

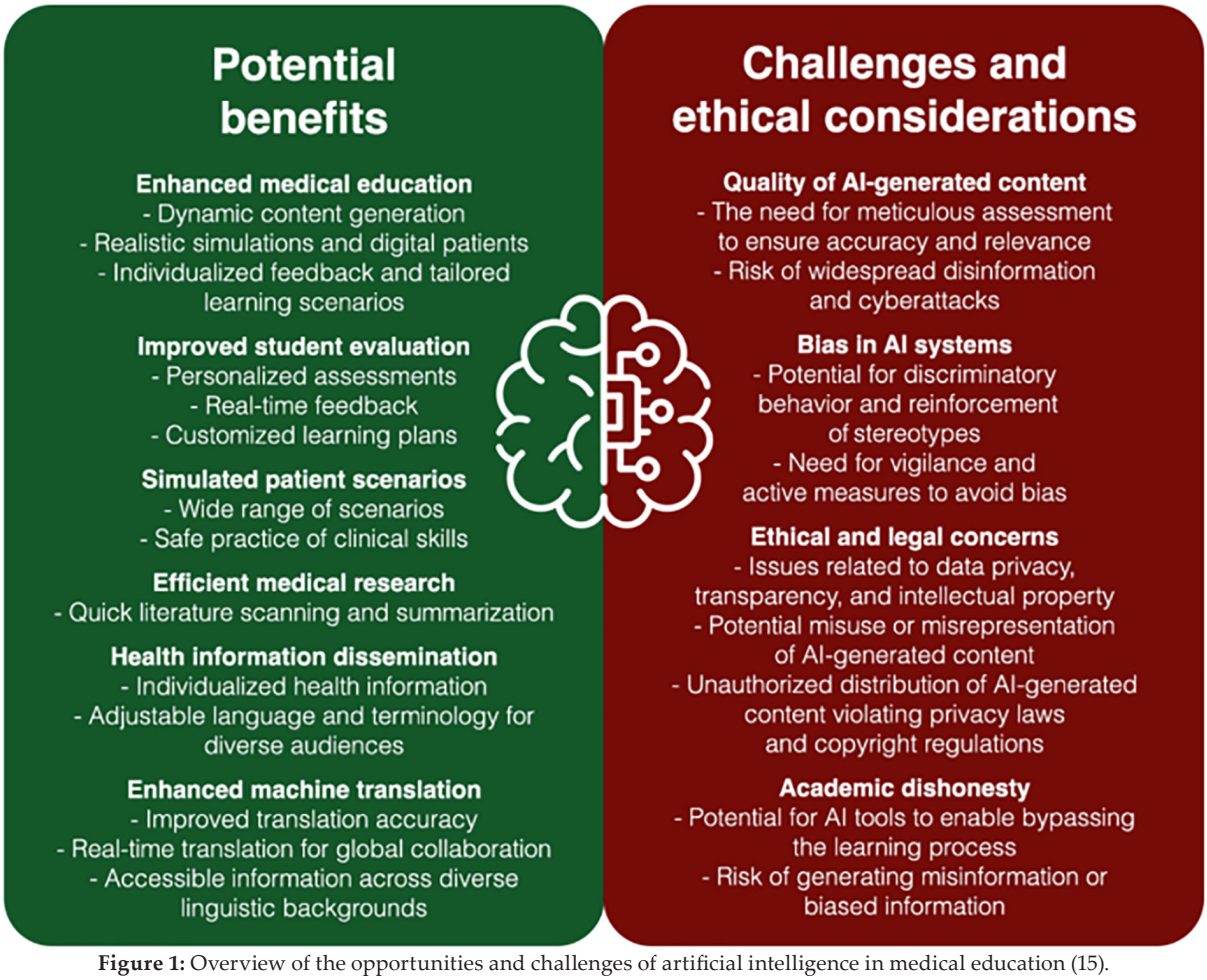

Figure 1: Overview of the opportunities and challenges of artificial intelligence in medical education (15).

comprehensive review of the opportunities and challenges presented by AI in medical education. While acknowledging the complexities of this evolving field, we primarily focus on the practical applications of AI within medical training. The distinctive aspect of this research lies in its use of the umbrella review method, which synthesizes the existing review research addressing AI in medical education. This approach provides deeper and more comprehensive findings regarding AI applications in medical education, thereby effectively addressing the gaps left by the previous individually conducted reviews.

Methods

The current study employed the umbrella review methodology to analyze the existing review literature and provide evidence on the applications of AI in medical education. An umbrella review synthesizes evidence from multiple reviews into a single comprehensive document, including systematic reviews that explore interventions or perspectives on a specific topic. This methodology is particularly recommended for addressing broad-scope issues where conflicting or divergent findings might arise.

To address the research objectives, the present umbrella review was performed to respond to the following question:

- What are the applications of AI in medical education, based on the review studies conducted?

Search Methods

To gather relevant studies, databases including Science Direct, Springer, ERIC, Emerald, Sage Journals, Wiley Online Library, PubMed, and Google Scholar were systematically searched for the review studies published from 2018 to 2024.

Our search and screening method followed a three-step process. Initially, we created a list of search terms. In the next step, we conducted a preliminary search with keywords like 'Artificial Intelligence AND Medical Education OR Systematic Review OR Scoping Review OR Meta-Analysis OR Narrative Review'. This resulted in developing the following keywords and combinations: 'Systematic Review of Artificial Intelligence+ (OR # AND) Education', 'Systematic Review of Artificial Intelligence+ (OR # AND) Medical Education', 'Scoping Review of Artificial Intelligence+ (OR # AND) Education', 'Scoping Review of Artificial Intelligence+ (OR # AND) Medical Education', 'Meta-Analysis of Artificial Intelligence+ (OR # AND) Education', 'Meta-Analysis of Artificial Intelligence+ (OR # AND) Medical Education', 'Narrative Review of Artificial Intelligence+ (OR # AND) Education', 'Narrative Review of Artificial Intelligence+ (OR # AND) Medical Education', 'Rapid Review of Artificial Intelligence+ (OR # AND) Education', 'Rapid Review of Artificial Intelligence+(OR # AND) Medical Education', 'Critical Review of Artificial Intelligence+ (OR # AND) Education', 'Critical Review of Artificial Intelligence+ (OR # AND) Medical Education', 'Theoretical Review of Artificial Intelligence+ (OR # AND) Education', 'Theoretical Review of Artificial Intelligence+ (OR # AND) Medical Education', 'Historical Review of Artificial Intelligence+ (OR # AND) Education', 'Historical Review of Artificial Intelligence+ (OR # AND) Medical Education', 'Mapping Review of Artificial Intelligence+ (OR # AND) Education', 'Mapping Review of Artificial Intelligence+ (OR # AND) Medical Education'.

The literature search was guided by the following inclusion and exclusion criteria:

• ***Inclusion Criteria***

- Relevance: Studies directly addressing the applications of AI in medical education
- Review Type: Systematic reviews, meta-analyses, or other comprehensive reviews synthesizing primary research findings
- Date Range: Articles published between 2018 and 2024
- Language: Only English-language publications
- Scope and Focus: Studies covering aspects relevant to AI applications in medical education

• ***Exclusion Criteria***

- Irrelevance: Studies not directly related to the research question (i.e., AI applications in medical education)
- Study Type: Research other than systematic reviews, meta-analyses, or comprehensive reviews, including informal reviews, conceptual articles, or case reports
- Duplication: Studies already included in other reviews that do not provide new insights
- Time Limitation: Articles outside the 2018-2024 publication range
- Language: Non-English studies
- Limited Scope: Studies examining specific AI aspects unrelated to medical education

Screening Process

Figure 2 illustrates the PRISMA flow chart detailing the literature search and screening process of the current umbrella review. The initial search of the databases led to the identification of a total of 362 studies. After screening the retrieved studies based on titles, abstracts, and keywords in accordance with the inclusion and exclusion criteria, a total of 77 reviews were deemed relevant.

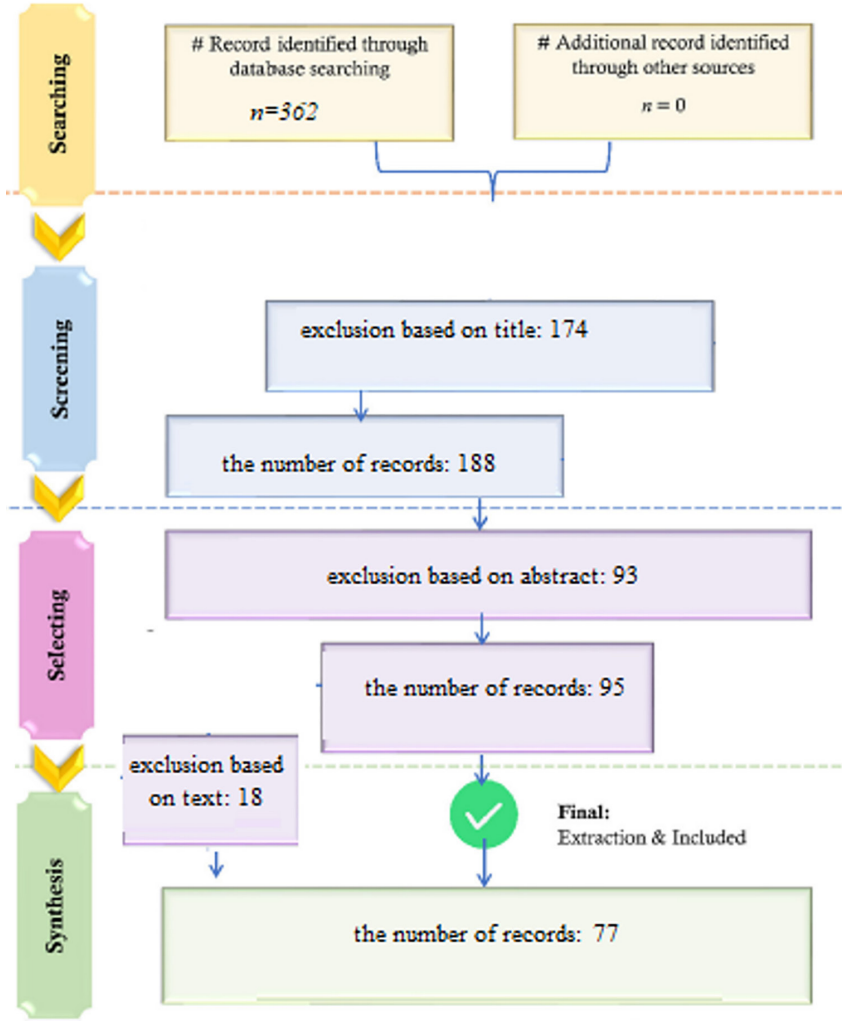

Figure 2: Research screening process based on the PRISMA flow chart

Quality Appraisal

The identified articles were reviewed and evaluated by three of the authors of the study, using the Critical Appraisal Skills Program (CASP). In the event of any disagreement among the researchers regarding the criteria, the matter was thoroughly discussed to reach a consensus. If a unanimous agreement could not be achieved, the opinion with the majority vote was ultimately considered for the final decision. Each researcher conducted an independent review and filled out the evaluation checklists according to established quality criteria. Following this individual assessment, the team collectively compared and discussed the results. Any differences in scoring or interpretation were thoroughly analyzed, and agreement was achieved through discussion or, when needed, by seeking input from a third expert. This collective approach was utilized with the aim of enhancing reliability, minimizing bias, and strengthening the overall validity of the quality assessment process. Table 1 presents the results of this evaluation. To ensure the inclusion of high-quality articles, we considered only those with an evaluation score greater than 50.

Data Abstraction

Data abstraction was carried out by four reviewers for each of the included studies, with all results meticulously recorded and managed in a centralized spreadsheet specifically designed for this project. Most of the reviews provided titles for their findings, which were extracted verbatim when available. A summary of the characteristics of each review is presented in Table 2.

Synthesis

For data analysis, the qualitative content analysis method was employed following the three-step approach of Elo and Kyngäs (95). Given the word limit, it was not possible to reference every article associated with each key concept. Consequently, the tables summarizing the research findings became quite lengthy.

Table 1: Quality assessment of selected articles based on the CASP

No.	Source	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
1	A meta-systematic review of artificial intelligence in higher education: a call for increased ethics, collaboration, and rigor	NO	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	80
2	A Meta-Analysis and Systematic Review of the Effect of Chatbot Technology Use in Sustainable Education	Yes	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	70
3	A meta-review of literature on educational approaches for teaching AI at the K-12 levels in the Asia-Pacific region	Yes	Yes	Yes	Yes	Yes	No	×	Yes	Yes	Yes	80
4	A Review of Artificial Intelligence (AI) in Education during the Digital Era	No	Yes	No	Yes	Yes	×	×	No	No	No	30
5	A Review of Artificial Intelligence (AI) in Education from 2010 to 2020	Yes	Yes	Yes	Yes	Yes	×	×	Yes	Yes	Yes	80
6	A Review of ChatGPT Applications in Education, Marketing, Software Engineering, and Healthcare: Benefits, Drawbacks, and Research Directions	No	Yes	No	No	×	×	×	No	No	No	10
7	A Review of Natural Language Processing in Medical Education	Yes	Yes	Yes	Yes	Yes	×	×	Yes	Yes	Yes	80
8	A Review on Artificial Intelligence in Education	No	Yes	No	No	Yes	×	×	No	No	Yes	30
9	A scoping review of artificial intelligence within pharmacy education	No	Yes	No	No	Yes	×	×	Yes	Yes	Yes	50
10	A systematic literature review of game-based learning in Artificial Intelligence education	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70
11	A Systematic Literature Review on the Applications of Robots and Natural Language Processing in Education	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70
12	A Systematic Review and Meta-Analysis of Artificial Intelligence Tools in Medicine and Healthcare: Applications, Considerations, Limitations, Motivation and Challenges	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
13	A systematic review of ChatGPT use in K-12 education	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70
14	A review study of ChatGPT applications in education	No	Yes	No	No	Yes	×	×	No	No	Yes	30
15	A Taxonomy of Various Applications of Artificial Intelligence in Education	No	Yes	No	No	Yes	×	×	No	No	No	20
16	Affordances and challenges of artificial intelligence in K-12 education: a systematic review	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
17	AI in Medical Education: Global situation, effects and challenges	No	Yes	No	No	Yes	×	Yes	Yes	No	Yes	50
18	An artificial intelligence educational strategy for the digital transformation	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70
19	Analyzing the role of ChatGPT as a writing assistant at higher education level: A systematic review of the literature	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70
20	Application of Artificial Intelligence in Medical Education: Current Scenario and Future Perspectives	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
21	Application of artificial intelligence in physical education: a systematic review	No	Yes	Yes	Yes	Yes	×	No	Yes	Yes	Yes	70
22	Application of ChatGPT in Higher Education and Research – A Futuristic Analysis	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	No	80
23	Applications and Challenges of Implementing Artificial Intelligence in Medical Education: Integrative Review	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70

No.	Source	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
24	Applications of Artificial Intelligence (AI) in Medical Education: A Scoping Review	No	Yes	Yes	No	Yes	×	No	Yes	No	Yes	50
25	Are We There Yet? - A Systematic Literature Review on Chatbots in Education	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70
26	Artificial Intelligence (AI) Adoption in the Medical Education during the Digital Era: A Review Article	No	Yes	No	No	Yes	×	No	No	No	No	20
27	Artificial Intelligence and Learning Analytics in Teacher Education: A Systematic Review	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70
28	Artificial Intelligence and Reflections from Educational Landscape: A Review of AI Studies in Half a Century	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
29	Artificial Intelligence and the Aims of Education: Makers, Managers, or Inforgs?	No	Yes	No	No	Yes	×	No	Yes	No	Yes	40
30	Artificial intelligence applications in Latin American higher education: a systematic review	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70
31	Artificial Intelligence Education Programs for Health Care Professionals: Scoping Review	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70
32	Artificial intelligence for healthcare and medical education: a systematic review	No	Yes	No	No	Yes	×	Yes	Yes	Yes	Yes	60
33	Artificial intelligence in higher education: the state of the field	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70
34	Artificial intelligence in intelligent tutoring systems toward sustainable education: a systematic review	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70
35	Artificial intelligence in medical education	No	Yes	No	No	Yes	×	Yes	Yes	No	Yes	50
36	Artificial intelligence in online higher education: A systematic review of empirical research from 2011 to 2020	No	Yes	Yes	No	Yes	×	No	Yes	Yes	Yes	60
37	Artificial Intelligence in Science Education (2013–2023): Research Trends in Ten Years	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
38	Artificial intelligence in special education: a systematic review	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
39	Artificial intelligence innovation in education: A twenty-year data-driven historical analysis	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70
40	Artificial Intelligence trends in education: a narrative overview	Yes	Yes	No	Yes	Yes	×	No	Yes	Yes	Yes	70
41	Artificial intelligence-based robots in education: A systematic review of selected SSCI publications	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70
42	Artificial Intelligence in Education: A Review	Yes	Yes	Yes	Yes	Yes	×	No	Yes	Yes	Yes	80
43	Artificial Intelligence in Undergraduate Medical Education: A Scoping Review	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
44	Artificial intelligence in science education: A bibliometric review	No	No	No	No	Yes	×	Yes	No	Yes	Yes	40
45	Benefits, Challenges, and Methods of Artificial Intelligence (AI) Chatbots in Education: A Systematic Literature Review	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
46	Chatbots applications in education: A systematic review	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70
47	ChatGPT and its impact on education	No	Yes	Yes	Yes	No	×	Yes	Yes	No	No	50
48	ChatGPT: Empowering lifelong learning in the digital age of higher education	Yes	Yes	No	Yes	Yes	×	Yes	Yes	Yes	Yes	80
49	ChatGPT for education and research: A review of benefits and risks	Yes	Yes	No	Yes	Yes	×	Yes	No	Yes	Yes	70

No.	Source	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
50	ChatGPT for Education and Research: Opportunities, Threats, and Strategies	Yes	Yes	No	Yes	Yes	×	Yes	Yes	Yes	Yes	80
51	ChatGPT for Teachers and Students in Science Learning: A Systematic Literature Review	Yes	Yes	Yes	Yes	Yes	×	No	No	Yes	Yes	70
52	ChatGPT in Education: An Opportunity or a Challenge for the Future?	Yes	Yes	Yes	Yes	Yes	×	No	No	No	No	50
53	ChatGPT Review: A Sophisticated Chatbot Models in Medical & Health-related Teaching and Learning	No	Yes	No	No	Yes	×	Yes	Yes	Yes	Yes	60
54	ChatGPT Utility in Healthcare Education, Research, and Practice: Systematic Review on the Promising Perspectives and Valid Concerns	Yes	Yes	No	Yes	Yes	×	Yes	Yes	Yes	Yes	80
55	ChatGPTBased Learning: Generative Artificial Intelligence in Medical Education	No	Yes	No	No	Yes	×	Yes	No	Yes	Yes	50
56	Data-Driven Artificial Intelligence in Education: A Comprehensive Review	Yes	Yes	No	Yes	Yes	×	No	Yes	Yes	Yes	70
57	Exploring the Potential of ChatGPT as an Educational Technology: An Emerging Technology Report	Yes	Yes	No	Yes	Yes	×	Yes	No	Yes	Yes	70
58	Exploring the Trend and Potential Distribution of Chatbot in Education: A Systematic Review	Yes	Yes	Yes	Yes	Yes	×	No	Yes	Yes	Yes	70
59	Generative Artificial Intelligence in Education and Its Implications for Assessment	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
60	Harnessing the power of artificial intelligence and ChatGPT in education – a first rapid literature review	No	Yes	Yes	No	Yes	×	No	No	Yes	Yes	50
61	How to harness the potential of ChatGPT in education?	No	Yes	No	No	Yes	×	Yes	Yes	Yes	Yes	60
62	Interacting with educational chatbots: A systematic review	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
63	Investigating the Use of Artificial Intelligence (AI) in Educational Settings: A Systematic Review	Yes	Yes	Yes	Yes	Yes	×	No	Yes	Yes	Yes	80
64	Mapping the global evidence around the use of ChatGPT in higher education: A systematic scoping review	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
65	Medical education trends for future physicians in the era of advanced technology and artificial intelligence: an integrative review	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
66	Navigating Generative AI (ChatGPT) in Higher Education: Opportunities and Challenges	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70
67	Opportunities and Challenges of ChatGPT in Academia: A Conceptual Analysis	Yes	Yes	No	Yes	Yes	×	Yes	Yes	Yes	Yes	80
68	Opportunities, Challenges, and Future Directions of Generative Artificial Intelligence in Medical Education: Scoping Review	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
69	Pedagogy of Emerging Technologies in Chemical Education during the Era of Digitalization and Artificial Intelligence: A Systematic Review	Yes	Yes	Yes	Yes	Yes	×	No	Yes	Yes	Yes	80
70	Personalized education and Artificial Intelligence in the United States, China, and India: A systematic review using a Human-In-The-Loop model	Yes	Yes	No	Yes	Yes	×	No	Yes	Yes	Yes	70

No.	Source	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
71	Perspectives of ChatGPT in Pharmacology Education, and Research in Health Care: A Narrative Review	Yes	Yes	No	Yes	Yes	×	Yes	Yes	Yes	Yes	80
72	Potentials of Chatbot Technologies for Higher Education: A Systematic Review	Yes	Yes	Yes	Yes	Yes	×	No	Yes	Yes	Yes	80
73	Power to the Teachers: An Exploratory Review on Artificial Intelligence in Education	Yes	Yes	No	Yes	Yes	×	Yes	Yes	Yes	Yes	80
74	Predicted Influences of Artificial Intelligence on Nursing Education: Scoping Review	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
75	Proactive and reactive engagement of artificial intelligence methods for education: a review	No	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	70
76	Rediscovering the use of chatbots in education: A systematic literature review	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
77	Role of AI chatbots in education: systematic literature review	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
78	Roles and research trends of artificial intelligence in higher education: A systematic review of the top 50 most-cited articles	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
79	Scoping review of artificial intelligence and immersive digital tools in dental education	Yes	Yes	Yes	Yes	Yes	×	No	Yes	Yes	Yes	80
80	A Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis of ChatGPT Integration in Nursing Education: A Narrative Review	Yes	Yes	No	Yes	Yes	×	Yes	Yes	Yes	Yes	80
81	Systematic literature review on opportunities, challenges, and future research recommendations of artificial intelligence in education	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
82	Systematic review of research on artificial intelligence applications in higher education – where are the educators?	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
83	The development of artificial intelligence in education: A review in context	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
84	The emergent role of artificial intelligence, natural learning processing, and large language models in higher education and research	Yes	Yes	No	Yes	Yes	×	Yes	Yes	Yes	Yes	80
85	The Importance of Artificial Intelligence in Education: A short review	Yes	Yes	Yes	No	Yes	×	Yes	Yes	Yes	Yes	80
86	The Influence of ChatGPT in Education: A Comprehensive Review	Yes	No	Yes	Yes	Yes	×	Yes	No	No	Yes	60
87	The opportunities and challenges of ChatGPT in education	No	Yes	No	No	Yes	×	No	Yes	Yes	Yes	50
88	The Potential of ChatGPT in Medical Education: Focusing on USMLE Preparation	No	Yes	No	No	Yes	×	No	No	No	No	20
89	The Promises and Challenges of Artificial Intelligence for Teachers: a Systematic Review of Research	Yes	Yes	Yes	Yes	Yes	×	No	Yes	Yes	Yes	80
90	The threat, hype, and promise of artificial intelligence in education	Yes	Yes	Yes	Yes	Yes	×	Yes	Yes	Yes	Yes	90
91	The Impact of the Use of ChatGPT in Enhancing Students' Engagement and Learning Outcomes in Higher Education: A Review	Yes	Yes	Yes	Yes	Yes	×	No	Yes	Yes	Yes	80

No.	Source	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
92	Transforming Education: A Comprehensive Review of Generative Artificial Intelligence in Educational Settings through Bibliometric and Content Analysis	Yes	Yes	No	Yes	Yes	×	Yes	Yes	Yes	Yes	80
93	Trends, Research Issues and Applications of Artificial Intelligence in Language Education	Yes	Yes	Yes	Yes	Yes	×	No	Yes	Yes	Yes	80
94	Use of Chatbots in E-Learning Context: A Systematic Review	Yes	Yes	Yes	Yes	Yes	×	No	Yes	Yes	Yes	80
95	What Is the Impact of ChatGPT on Education? A Rapid Review of the Literature	No	Yes	Yes	No	Yes	×	No	Yes	Yes	Yes	60

Q1. Was there a clear statement of the aims of the research? Q2. Is a qualitative methodology appropriate? Q3. Was the research design appropriate to address the aims of the research? Q4. Was the recruitment strategy appropriate to the aims of the research? Q5. Was the data collected in a way that addressed the research issue? Q6. Has the relationship between researcher and participants been adequately considered? Q7. Have ethical issues been taken into consideration? Q8. Was the data analysis sufficiently rigorous? Q9. Is there a clear statement of findings? Q10. How valuable is the research?

Table 2: Summary of selected studies

Reference number	Review focus	Number of studies	Name(s) and timeframe of searching databases	Published journal	Country
(16)	Artificial Intelligence in Education (AIEd)	66	Web of Science, Scopus, ERIC, EBSCO Host, IEEE Xplore, ScienceDirect and ACM Digital Library, or captured through snowballing in Open Alex, ResearchGate and Google Scholar (2018 and July 2023)	International Journal of Educational Technology in Higher Education	England
(17)	Use of chatbot technology in education	32	Web of Science, Wiley Online Library, Springer Link, Taylor & Francis Online, Elsevier ScienceDirect, and Google Scholar (2010 to 2022)	Sustainability/ The Use of Digital Technology for Sustainable Teaching and Learning	China
(18)	Artificial Intelligence in Education	14	Education Resources Information Center (ERIC), IEEE, Education Research Complete, Web of Science, Scopus, and Google Scholar (2018 to 2021)	Computers and Education: Artificial Intelligence	China
(19)	Artificial Intelligence in Education	100	Web of Science database and the Social Science Citation Index (SSCI) journals (2010-2020)	Complexity	China
(20)	Natural Language Processing in Medical Education	13	PubMed (Not mentioned)	Western Journal of Emergency Medicine	United state
(21)	Game-based Learning in Artificial Intelligence	125	ISI Web of Science, Scopus, and Google scholar (without setting restriction on the publication period)	Interactive Learning Environments	China
(22)	Robots and Natural Language Processing	82	the Scientific Journal Rankings (SJR) website, the study samples included twelve reliable/high-reputation scientific journals (2014-2023)	Electronics	Malaysia
(23)	Artificial Intelligence in Medicine	82	Taylor and Francis, Google Scholar, Scopus, Web of Science, Elsevier, Springer, MDPI, IEEE Xplore digital, and Wiley (November 2022 and August 2023)	Diagnostics	Iraq
(24)	ChatGPT in education	13	Web of Science (WOS), Scopus, ERIC, SpringerLink, IEEE Xplore, and ACM Library (2022-2023)	European Journal of Education	Spain
(25)	Artificial Intelligence in Education	-	Not mentioned	International Journal of Artificial Intelligence in Education	-

Reference number	Review focus	Number of studies	Name(s) and timeframe of searching databases	Published journal	Country
(26)	Artificial Intelligence in Education	169	Wiley Online Library, JSTOR, Science Direct, and Web of Science (2011 to 2021)	Journal of Research on Technology in Education	USA
(27)	Artificial intelligence in education	-	-	International Journal on Interactive Design and Manufacturing	Mexico
(28)	ChatGPT in higher education	30	Scopus, Science Direct, PubMed, and Web of Science (WoS) (December 2022 to May 2023)	Contemporary Educational Technology	Saudi Arabia
(29)	Artificial Intelligence in Medical Education	Not mentioned	PubMed, ResearchGate, PubMed Central, Web of Science, and Google Scholar (2002-2022)	Journal of Advances in Medical Education & Professionalism	Saudi Arabia
(30)	Artificial intelligence in physical education	130	SCI EXPANDED and SSCI indexes (January 2010 to March 2023)	Education and Information Technologies	China
(31)	ChatGPT in Higher Education	-	Google Scholar and AI-based GPTs	International Journal of Applied Engineering and Management Letters	India
(32)	Artificial Intelligence in Medical Education	37	EBSCOhost Education Resources Information Center and Education Source (1983 to March 2019), and Web of Science (1983 to March 2019)	JMIR Medical Education	Singapore
(33)	Chatbots in Education	74	Web of Science, Google Scholar, Microsoft Academics, and the educational research database "Fachportal Pädagogik" (including ERIC)(not mentioned)	Frontiers in artificial intelligence	Germany
(34)	Artificial Intelligence in education	30	Web of Science, ScienceDirect, and IEEE Xplore (2017-2021)	Education science	China
(35)	Artificial Intelligence in education	279	Scopus (-)	Sustainability	Turkey
(36)	Artificial intelligence in higher edu	31	Web of Science, IEEE Xplorer, Scielo, and CAPES Portal (July 2016 to June 2021)	International journal of educational technology in higher education	China
(37)	Artificial intelligence in health care	41	n Google Scholar (not mentioned)	JMIR Medical Education	Canada
(38)	Artificial intelligence in healthcare	25	PubMed, Embase, Cochrane, and Chinese database CNKI from (2017 to July 2022)	American journal of translational research	China
(39)	Artificial intelligence in higher education	138	EBSCOhost, Wiley Online Library, JSTOR, Science Direct, and Web of Science (2016 to 2022)	International Journal of Educational Technology in Higher Education	USA
(40)	Artificial intelligence in education	73	Scopus, Web of Science (SSCI) (2014-2023)	Smart Learning Environments	China
(41)	Artificial intelligence in higher education	32	Web of Science, Scopus, ACM, IEEE, Taylor & Francis, Wiley, EBSCO (from January 2011 to December 2020)	Education and Information Technologies	China
(42)	Artificial Intelligence in Education	76	Web of Science and Scopus (from 2013 to 2023)	Journal of Science Education and Technology	China
(43)	Artificial Intelligence in Education	29	SCOPUS, EBSCO, ERIC, CORE Scholar, SCIExpanded, SSCI, ThinkIR, TR Dizin (January 2000 to June 2020)	Interactive Learning Environments	Turkey
(44)	Artificial Intelligence in Education	425	Association for Computing Machinery (ACM), EBSCO, Emerald, IEEE, JSTOR, ScienceDirect, Taylor & Francis, and Wiley (2000 to 2019)	International Journal of Innovation Studies	Singapore

Reference number	Review focus	Number of studies	Name(s) and timeframe of searching databases	Published journal	Country
(45)	Artificial Intelligence in Education	Not mentioned	ScienceDirect, Google Scholar, Emerald, Forbes, AI Magazine, Gartner, Times, and governmental reports (after 2012)	Procedia Computer Science	France
(46)	Artificial Intelligence in Education	13	Web of Science (WOS) (2019-2021)	Computers and Education: Artificial Intelligence	Taiwan
(47)	Artificial Intelligence in Education	30	g EBSCOhost, ProQuest, Web of Science, Google Scholar (2009 TO2019)	IEEE Access	China
(48)	Artificial Intelligence in Medical Education	22	Medline, Embase, PubMed, Scopus, ERIC, Med EdPortal, and Cochrane Library (January 1, 2000, and onward)	Emerging Approaches	Canada
(49)	(AI) Chatbots in Education	37	e Web of Science database (not mentioned)	International Journal of Technology in Education	Turkey
(50)	Chatbots s in education	53	IEEE Digital Library, ScienceDirect, SpringerLink, Scopus, Taylor and Francis, ERIC (until May 2021)	Computers and Education: Artificial Intelligence	South Africa
(51)	ChatGPT in higher education	-	-	Education and Information Technologies	Lebanon
(52)	ChatGPT in education	-	-	Cambodian Journal of Educational Research	United Kingdom
(53)	ChatGPT in education	-	-	Applies sciences	Bangladesh
(54)	ChatGPT in education	40	All databases (2015-2023)	Journal Penelitian Pendidikan IPA	Indonesia
(55)	ChatGPT in education	5,537,942 users, and 125,151 conversations.	Twitter (November 30, 2022, to January 31, 2023)	Scientific reports	Germany
(56)	ChatGPT in medical	32	PubMed from year since beginning	Malaysian Journal of Medicine and Health Sciences	Malaysia
(57)	ChatGPT in Healthcare	60	PubMed/MEDLINE and Google Scholar (2022-2023)	Healthcare	Amman
(58)	Artificial Intelligence in Education	-	Not mentioned (2014-2022)	IEEE Transactions on Learning Technologies	Ireland
(59)	ChatGPT in education	-	-	Technology, Knowledge and Learning	USA
(60)	Chatbot in Education	25	Ebscohost, Emerald, ScienceDirect, SpringerLink, and Scopus (between 2016 and 2021)	International Journal of Information and Education Technology	Malaysia
(61)	Artificial Intelligence in Education	-	-	TechTrends	USA
(62)	ChatGPT in education	-	-	Knowledge Management & E-Learning	Hong Kong
(63)	Chatbots in Education	36	ACM Digital Library, Scopus, IEEE Xplore, and SpringerLink (2011 – 2021)	Education and Information Technologies	United Arab Emirates
(64)	Artificial Intelligence in Education	Not mentioned	ACM porta, IEEE Xplore, ScienceDirect, Springer	Software and Services Process Improvement.	Spain
(65)	ChatGPT in higher education	69	Google Scholar, Taylor and Francis, Emerald, Sage, Elsevier, Science Direct, and PubMed on May 30, 2023	Education and Information Technologies	Pakistan

Reference number	Review focus	Number of studies	Name(s) and timeframe of searching databases	Published journal	Country
(66)	artificial intelligence in medical education	28	PubMed, Scopus, Web of Science, and EBSCO ERIC (between 2011 and 2017)	BMC Medical Education	South Korea
(67)	AI (ChatGPT) in Higher Education	Not mentioned	ERIC, Cite Seer X, ScienceDirect, Web of Science, ProQuest, JSTOR, Scopus, SpringerLink and Google Scholar	Smart Learning for A Sustainable Society	Australia
(68)	ChatGPT in education	-	-	--	Bangladesh
(69)	Artificial Intelligence in Medical Education	41	PubMed, Web of Science, and Google Scholar databases (from January 1, 2022, to June 21, 2023)	JMIR Medical Education	USA
(70)	Artificial Intelligence in Chemical Education	45	Web of Science, Scopus, and the Educational Information Resource Center (between 2010 and 2021)	Education sciences	China
(71)	Artificial Intelligence in education	1709	IEEE (2019–2021)	Computers and Education: Artificial Intelligence	India
(72)	ChatGPT in Pharmacology Education	-	-	Journal of Pharmacology and Pharmacotherapeutics	India
(73)	ChatGPT in Higher Education	50	ACM Digital library, IEEExplore, Scopus (from 2015 onwards)	UK academy for information system	Germany
(74)	Artificial Intelligence in Education	141	EBSCO, Web of Science, and Scopus (2008–2020)	Information	UK
(75)	Artificial Intelligence in Nursing Education	27	MEDLINE, Cumulative Index of Nursing and Allied Health Literature, Embase, PsycINFO, Cochrane Database of Systematic Reviews, Cochrane Central, Education Resources Information Centre, Scopus, Web of Science, and Proquest (last 5 years)	JMIR Nursing	Canada
(76)	Artificial Intelligence in Education	195	Google Scholar (over the past 20 years)	Frontiers in Artificial Intelligence	USA
(77)	chatbots in education	80	Scopus, Science Direct, ACM, IEEE Xplore, Web of Science, ERIC database, and Wiley (September to November 2019 and in May 2020)	Computer Application English Education	Spain
(78)	AI chatbots in education	67	ACM Digital Library, Scopus, IEEE Xplore, and Google Scholar (2018–2023)	International Journal of Educational Technology in Higher Education	Kuwait
(79)	Artificial intelligence in higher education	50	WoS database and reviewed the bibliographies of all relevant articles (not mentioned)	Australasian Journal of Educational Technology	Taiwan
(80)	Artificial intelligence in dental education	31	Google Scholar, PUBMED, web of science, embase, cochrane library (2018 to May 19, 2021)	American Dental Education Association.	USA
(81)	ChatGPT in Nursing	Not mentioned	PubMed, Scopus, and Google Scholar	Cureus	Qatar
(82)	Artificial intelligence in education	92	ERIC, ProQuest, Scopus, and Web of Science (WOS) (from January 1, 2012, to October 24, 2021)	Computers and Education: Artificial Intelligence	China
(83)	Artificial intelligence in education	146	EBSCO Education Source, Web of Science and Scopus (2007 – Nov 2018)	International Journal of Educational Technology in Higher Education	Germany
(84)	Artificial intelligence in education	-	-	Journal of computer assisted learning	USA

Reference number	Review focus	Number of studies	Name(s) and timeframe of searching databases	Published journal	Country
(85)	Artificial intelligence in higher education	-	-	Research in Social and Administrative Pharmacy	Saudi Arabia
(86)	Artificial Intelligence in Education	-	-	Journal of Review in Science and Engineering	Turkey
(87)	ChatGPT in Education	12	Web of Science, Scopus, and Google Scholar (between May and June 2023)	International Journal of Recent Research Aspects	Ethiopia
(88)	Artificial Intelligence in education	44	Wos (last 20 years until 14 September 2020)	Tech Trends	Finland
(89)	Artificial intelligence in education	20	Google Scholar and Mid Sweden University library (between 2020 and 2022)	Artificial Intelligence	Sweden
(90)	ChatGPT in higher education	-	-	International Journal of Academic Research in Business and Social Sciences	Malaysia
(91)	Artificial Intelligence in Education	207	Scopus (2018 to 2023)	Sustainability	UAE
(92)	Artificial Intelligence in Education	516	Web of Science (WoS), Education Resource Information Center (ERIC), and Scopus (2000-2019)	Educational Technology & Society	China
(93)	Chatbots in E-Learning	20	IEEE ScienceDirect ACM Digital Libraries Springer (2017-2022)	Not mentioned	Indonesia
(94)	ChatGPT in Education	50	1) Academic Search Ultimate, 2) ACM Digital Library, 3) Education Research Complete, 4) ERIC, 5) IEEE Xplore, 6) Scopus, and 7) Web of Science (1 January 2022 to 28 February 2023)	Education sciences	China

The analysis process consisted of the following steps:

- Data Preparation: Key sections of the selected articles were meticulously reread multiple times. With the "paragraph" being considered as the unit of analysis, key concepts related to the research objective were extracted from the text.
- Data Organization: The extracted key concepts were categorized based on their similarities and differences, and subsequently organized into broader, more abstract categories.
- Reporting the Results: The final findings from the data analysis were comprehensively presented in detail in the Results section.

Data Validation

To ensure the accuracy and validity of the qualitative data, we employed the following methods: (a) Presentation of Results to Experts: The analyses and preliminary findings were presented to experts, and their feedback was incorporated. (b) Researcher Consensus: The results were discussed among the four researchers to reach a consensus on the findings.

Results

First, a statistical description of the results will be provided. Subsequently, the findings from the qualitative content analysis will be presented. Figure 3 illustrates the number of published articles categorized by countries.

The investigation of the geographic distribution of the included studies demonstrated that China had the highest number of articles published in this field, followed by the United States, with Malaysia, Saudi Arabia, and Turkey jointly sharing the third position. Figure 4 illustrates the distribution of the selected articles across various journals.

As displayed in Figure 4, the following three journals had the highest number of articles about AI in medical education: *International Journal of Educational Technology in Higher Education*, *Computers and Education: Artificial Intelligence*, and *Education and Information Technologies*, each featuring five articles. Table 3 provides a summary of the status of these journals.

The results of the qualitative content analysis are summarized in Table 4. As outlined earlier, the analysis was conducted in three stages.

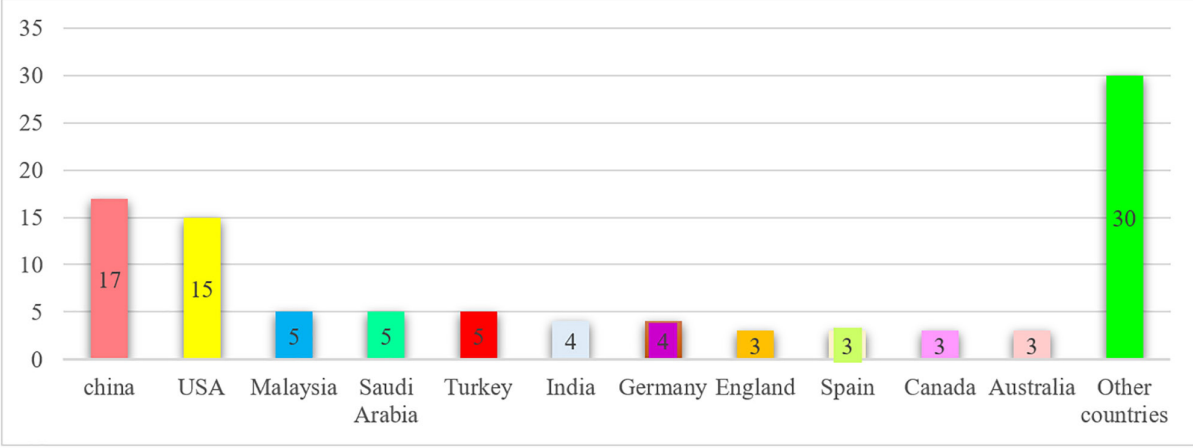

Figure 3: Distribution of articles by country

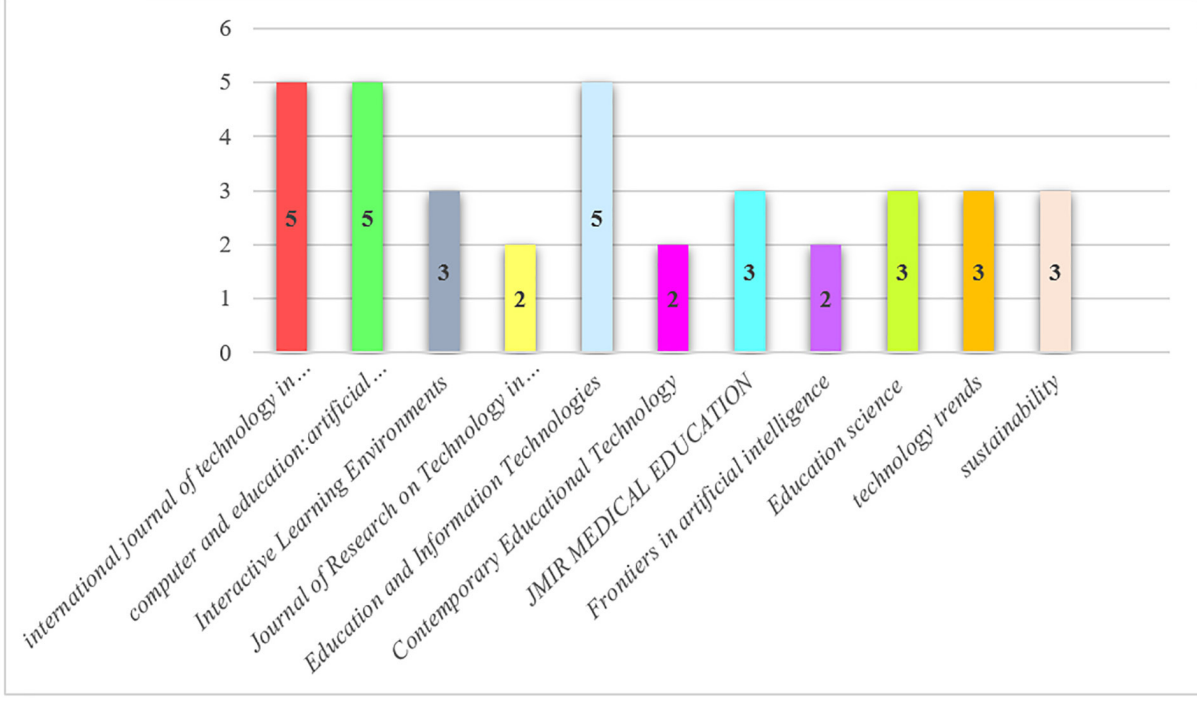

Figure 4: Distribution of articles by journal

Table 3: Summary of the status of the journals with the highest number of published articles about AI in medical education

Journals	Best Quartile	Impact Factor (2023)	5 Years (IF)	Cite Score (2023	SJR (2023)	H index (2023)
Education and Information Technologies	Q1	4.8	4.8	10	1.301	76
Computers and Education: Artificial Intelligence	Q1	*	*	16.8	3.227	29
International Journal of Educational Technology In Higher Education	Q1	8.6	9.9	19.3	2.578	61

Initially, the most significant key concepts were identified. Next, these concepts were grouped into themes based on their similarities and differences. Finally, examples of applications were provided for each theme.

As already detailed in Table 4, the review of the included studies led to the identification of the following six main themes: faculty members, students, the teaching and learning process, assessment, curriculum, and management and implementation. Figure 5 depicts the frequency of these themes across the reviewed studies.

As shown in Figure 5, the highest percentage corresponds to the teaching and learning process, accounting for 25.9%. This is closely followed by management and implementation at 25.6%.

Table 4: Results of qualitative content analysis

Themes	Key concepts	Application example
Faculty Members	Assisting in intelligent attendance management; Personal feedback; Reducing workload; Assisting in planning and managing tasks; Optimizing time management; Assisting in educational design; Assisting in self-development; Assisting in adapting to new teaching methods; Diverse teaching styles; As an educational and research assistant; Assisting in formulating and realizing educational goals; Assisting in developing new educational plans and ideas; Using educational robots as assistants; Assisting in diversifying educational assistance tools; Facilitating and managing various tasks; Assisting in compiling higher-quality articles; Assisting in pedagogical innovation; Assisting in updating personal knowledge; Assisting in deeper understanding of medical terms and concepts; Project management support; Assisting in identifying students' learning goals and knowledge gaps; Improving clinical decision-making skills; Assisting in developing digital competencies; Developing career paths; Assisting in identifying one's strengths and weaknesses; Assisting in developing emerging educational theories; Assisting in identifying learning styles; Assisting in diagnosing specific learner problems with early intervention; Developing evidence-based educational approaches; Assisting in designing interdisciplinary activities; Provide data-driven insights that inform instructional decisions; Help customize instructional approaches; Help access unlimited instructional resources; Help design and develop student-centered activities; Help write comprehensive lesson plans; Help create engaging classroom activities; Help create solutions for complex tasks; Help take a scenario-based approach to instruction; Help select adaptive and student-centered teaching strategies; Help deliver multilingual and multicultural instruction; Help adapt to the pace of change in the workplace; Help better communicate course content; Help provide adaptive teaching strategies; Help determine optimal content delivery; Help develop global knowledge.	- An artificial intelligence-based system can analyze students' textual feedback to identify patterns related to faculty members' strengths (such as the ability to explain complex concepts) and weaknesses (such as lack of interaction with students). - Artificial intelligence can help to write a comprehensive lesson plan by analyzing the content of similar courses and suggesting objectives, headings, and standard assessment methods. - AI can reduce faculty workload by automating administrative tasks such as grading tests, managing grades, and responding to repetitive emails. - AI can automatically manage student attendance and provide accurate reports using facial recognition or analysis of check-in and check-out data.
Students	Helping students with special needs; Providing personal feedback; Helping students optimize their academic decisions; helping to develop career paths; Reducing workload; Individualized instruction and planning; Programming training; Strengthening writing skills; Helping with preparation before entering the classroom; Helping with the development of metacognitive skills; As a private tutor; Helping with self-organization; Strengthening reasoning power; Helping to increase English language proficiency; Improving clinical competence; Improving patient care skills; Preparing for future skills; Helping to summarize articles and books; Helping to better solve course problems; Helping to understand complex medical ideas more deeply; Helping with self-regulation; Helping with self-monitoring; Encouraging participation in discussions and discussions; Study assistant; Helping to prepare for exams; Always available; Helping with laboratory work; Evidence-based practice; As a research assistant; Helping with self-study; Helping in assessing your own competencies in each course; Helping with homework; Reducing superficial stress levels; Increasing self-confidence; Developing problem-solving skills; Providing academic counseling services; As a mentor for students; helping to reduce cognitive load; encouraging reflection and analysis; helping to manage emotions; helping with academic integration.	- AI can provide personalized and immediate feedback by analyzing student performance on assignments and tests to identify their strengths and weaknesses. - AI can help students prepare before entering the classroom by providing summaries, interactive exercises, and content-based readiness tests. - Using intelligent learning platforms that automatically suggest courses and educational resources tailored to each student's knowledge level and individual needs, in addition to providing immediate feedback exercises and tests to reinforce learned concepts. - AI can help students with special needs access educational resources and interact with lessons by providing tools such as speech-to-text conversion, automatic language translation, or virtual classrooms with customizable content.

Themes	Key concepts	Application example
Teaching and Learning Process	Smart learning process; Intelligent recommender systems in the learning process; Adaptive learning; Interdisciplinary learning; Sharing big data in learning; Customizing learning; Increasing learning motivation; Developing collaborative learning; Analyzing emotions in learning; Suggesting more resources for learning; Accessing and searching for huge resources for learning; Diverse learning paths; Developing an online learning approach; learning analysis; Virtual patient simulator in learning; Virtual reality in education; Helping in designing learning simulations; Personalizing learning; Simplifying the learning process; Increasing learning opportunities; Accessible learning; Free learning; Interactive learning environments; Self-efficacy in learning; Developing learning activities; Project-based learning; Active learning; Maximizing learning efficiency; Smart learning environment; Game-based learning; Increasing creativity in learning; Step-by-step learning; Collaborative learning; Learning in small groups; Adapting to different learning styles; Virtual and augmented reality in learning; Blended learning; Developing data-based learning paths; Shortening learning time; Increasing learning quality; Increasing learning outcomes; Lifelong learning; Image processing-based learning; Increasing the quality of learning experiences; Problem-based learning; Case-based learning; Making the learning process interesting; mobile-based learning; increasing the speed of learning; computer-based learning; interdisciplinary learning; scaffolder learning; self-regulated learning; open learner; transformative learning; digital learning; helping to manage learning; exploratory learning; customized learning; dynamic learning; creating new learning patterns; learning anytime, anywhere; identifying learning needs; flipped learning; deep learning; group learning; story-based learning; emotional learning; app-based learning; learning through social media; changing learning habits; multimodal learning; situational learning; creating constructivist learning activities; preferred approaches to learning; developing virtual avatars in learning; more enjoyable learning; purposeful learning; developing concept maps for learning; sensor-based learning; holistic learning; supportive learning environments; autonomy in learning.	- By analyzing student learning and performance data, AI can create customized learning paths that adapt educational content and exercises based on the needs and pace of each student. - By using sentiment analysis in students' text or audio feedback, AI can identify their emotions, such as stress, fatigue, or satisfaction, and help faculty members adjust teaching approaches based on students' emotional states. - By designing interactive educational games that are tailored to students' levels and needs, AI can make the learning experience more engaging and help reinforce educational concepts through motivating challenges and rewards. - By creating interactive stories that present educational content in the form of engaging narratives and decision-based simulations, AI can help students understand concepts more deeply and actively participate in the learning process.
Assess-ment	Personalizing assessment; Developing adaptive assessment; Profiling learner performance over time for assessment; Automated scoring; Developing online tests; Automated feedback; Identifying students at risk of low academic performance and implementing interventions; Automated grading; Helping evaluate teaching effectiveness; Timely assessment; Increasing the accuracy of the assessment process; Diversifying assessment methods; Developing online assessment; More reliable assessment; Developing intelligent tracking of learners; Automated exam correction; Intelligent assignment correction; Step-by-step assessment of academic progress; Helping design assessment rubrics; Helping design online tests; Preparing question banks; Managing assessment processes; Helping design assignments; Improving self-assessment processes; Helping to more accurately assess faculty performance; Developing critical assessment; Helping to design new assessment mechanisms; Student-centered assessments; Targeted and personalized feedback; Improving the quality of assessment feedback; Helping with daily performance assessment; Simulating test questions; Timetable for assessing assignments; More accurate grading in assessment; Improving the quality of test questions; Reducing assessment pressure; Providing a standard framework in assessment; Collective assessment; Formative assessment; Assisting in the design of exercises and assignments; Developing multiple assessment approaches; Reducing human error in assessment; Fair assessments; Assisting in the analysis of learner data from multiple sources; Discovering correlations between learning behaviors and learner performance; Systematic assessment of learning needs; Inventing new assessment methods.	- AI can analyze student performance and identify their strengths and weaknesses, creating personalized assessments that include questions and exercises tailored to each student's individual needs. - AI can use natural language processing and machine learning algorithms to automatically score text-based and multiple-choice tests and provide students with immediate and accurate feedback. - AI can analyze student performance and identify learning needs, design intelligent online tests that adapt questions based on the student's knowledge level and provide immediate and personalized feedback. - AI can analyze student performance data, identify risk patterns in their grades and activities (such as absenteeism or persistent low grades) and predict the likelihood of poor performance, and automatically suggest appropriate educational interventions (such as counseling or support resources).

Themes	Key concepts	Application example
Curriculum	Curriculum personalization; Curriculum enrichment; Assistance in curriculum design; Development of experiential curriculum; Improving the quality of curriculum; Multilingual curriculum; Curriculum support; Development of adaptive curriculum; Assistance in developing interdisciplinary curriculum; Curriculum digitization; Assistance in analyzing curricula; Assistance in organizing curriculum sequences; Curriculum integration; Free curriculum; Competency-based curricula; Assistance in redesigning curricula; Development of medical curricula based on labor market needs; Multi-layered curriculum; Curriculum innovation.	- By analyzing student performance data and learning preferences, AI can provide personalized course content that is tailored to each student's individual needs, learning styles, and pace of progress. - By analyzing data from different disciplines, identifying commonalities and challenges, and providing suggestions for designing interdisciplinary curricula, AI can help develop programs that provide students with an effective combination of knowledge and skills. - By analyzing student performance data, educational trends, and current clinical needs, AI can provide suggestions for redesigning medical curricula so that educational content is up-to-date, comprehensive, and tailored to student needs and scientific advances.
Management and Implementation	Predicting student dropout; Predicting student retention rates; Predicting student enrollment rates; Developing educational standards; Data-based decision-making; Helping analyze big educational and research data; Developing smart virtual laboratories; Developing smart campuses; Reducing management costs; Realizing educational equity; Reducing the workload of managers and staff; Increasing the quality of patient care; Improving the patient care process; Helping to update medical guidelines; Helping to address patient questions; Helping to provide new treatment tips; As a huge source of medical information; Developing patient interaction simulation; Simplifying medical reporting; Promoting a patient-centered care approach; Increasing medical text production; Improving the accuracy of medical diagnoses; Developing user-friendly interactions in medicine; Developing new therapeutic drugs; Helping to analyze big medical data; Predicting future medical trends and keeping up with them; Facilitating patient-physician communication; Improving the quality of medical reporting; Optimizing clinical workflow; Helping with treatment planning; Helping to manage patient records; Unified production of clinical notes; Helping to address communication challenges in hospitals; Bridging the communication gap between healthcare providers and patients; Increasing patient understanding; Improving the quality of medical consultations; Supporting medical decision-making; Developing patient support mechanisms; Improving healthcare systems; Improving the quality of medical surgeries; Helping to improve the quality of medical tests; Helping to improve medical knowledge; Increasing patient satisfaction; Improving interactions in non-English medical environments; Developing image-based medicine; Assisting in treatment decisions; A tool for medical practice; Providing innovative solutions in medicine; Increasing the quality of pharmaceutical care processes; Improving intraoperative techniques; Reducing long-term complications in medicine; Efficient data-driven insights in medicine; Helping in early diagnosis of disease; Personalizing treatment; Reducing human error in treatment; Streamlining medical automation; Accurate profiling of patient information; Increasing the effectiveness of medical documentation; Helping to formulate and develop medical protocols; Developing new healthcare innovations; Eliminating medication errors; Developing hospital information systems; Developing targeted treatment plans; Developing clinical scenario simulations; Developing empathy and communication skills with patients; More accurate prediction of patient outcomes; Optimizing treatment plans; Minimizing surgical errors; Increasing empathy in patient care; Increasing the quality of education; Developing clinical thinking and judgment; Creating dashboards to support real-time monitoring and decision-making; Helping to more accurately interpret medical images; Managing physician tasks; Providing medical consultation services; Developing health literacy; Providing timely and accurate information to patients; Generating quality medical reports; Identifying and validating new drug targets; Increasing cost-effectiveness of treatment; Helping to identify patterns in medical data; Helping to create scenarios in treatment; Providing evidence-based practice guidelines; Managing personnel data.	- AI can improve the quality of patient care by analyzing patient data, predicting disease trends, and providing personalized treatment solutions, and help doctors make optimal decisions. - AI can improve the accuracy of medical diagnoses by analyzing medical data and medical images, identifying complex patterns, and providing more accurate predictions, helping doctors diagnose diseases faster and more accurately. - AI can analyze medical images such as scans and radiographs using deep learning algorithms and facilitate more accurate diagnosis of diseases, identify abnormalities, and predict treatment trends. This can help develop image-based medicine. - AI can facilitate the automation of medical documentation by using natural language processing and record medical data faster and more accurately, which helps doctors spend more time caring for patients and reduce documentation errors.

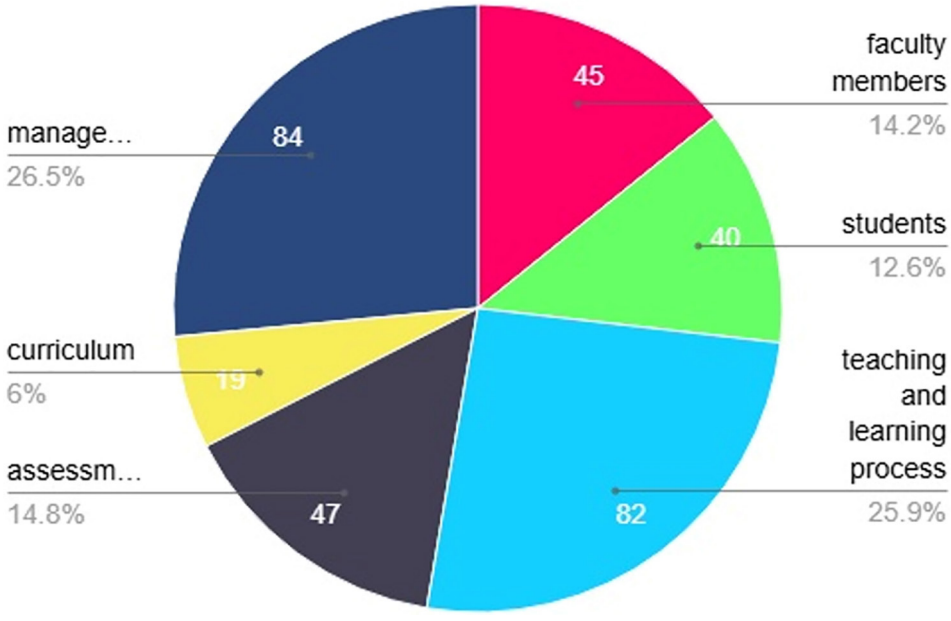

Figure 5: Frequency of the identified themes across the reviewed studies

Assessment comes next at 14.8%, followed by faculty members and students at 14.2% and 12.6%, respectively. The curriculum holds the lowest percentage, ranking last at 6%.

Discussion

This study aimed to explore AI applications in medical education. To this end, relevant review studies were identified and analyzed. The results of the analysis led to the identification of six main themes, as discussed in detail in the following sections:

§ Faculty Members

In today's global environments, faculty members play a crucial role in contributing to the achievement of higher education objectives (96). They serve as the vanguard of education, research, and the provision of advisory and entrepreneurial services. By nurturing skilled graduates, faculty members hold a central role in the overall functioning of universities (97). The integration of AI into education offers significant benefits for faculty members by facilitating improved time management and reduced workload. This, in turn, contributes to increased effectiveness and productivity in fulfilling their responsibilities (98). Machine learning algorithms assist faculty members in systematically monitoring student performance in class (99). The faculty can also leverage deep learning to monitor learner attendance through precise facial recognition (100). Moreover, robots, acting as teaching assistants, provide the faculty with advice and support, thereby enhancing their work quality (101). The AI's capability to analyze vast datasets generated from student interactions with educational technologies can provide the faculty members with deep insights into students' learning behaviors, performance trends, and cognitive tendencies (102). Additionally, AI can offer guidance, strategies, and recommendations tailored to the educational needs of students, thereby equipping the faculty members with insights into facilitating personalized learning (103). This support empowers faculty members to identify and address weaknesses in their teaching methods and improve the efficiency of their knowledge transfer promptly, fostering opportunities for self-development (104). As the reviewed studies indicated, AI presents a broad spectrum of applications for faculty members in the field of medical education with the potential to reduce their workload while simultaneously enhancing the quality of their work and performance (18, 21, 31, 40, 52).

§ Students

Medical students and the implementation of programs which aim at their development play a critical role in enhancing their performance and increasing their efficiency as the human capital of the university (105). One of the key applications of AI for students is supporting personalized learning, where students learn and progress at their own pace and tailor their learning methods with AI assistance. This approach enables students to select and explore topics they are genuinely interested in (106). Another significant application of AI is its ability

to allow for the simulation of educational and practical environments, providing students with an opportunity to practice essential skills. This is particularly valuable in medical education, where AI-powered virtual reality is used for surgical training. AI can also help students identify and acquire the essential skills relevant to the modern workforce, such as programming and data analysis (107). Moreover, it enhances the support students receive from their instructors, alleviating the anxiety often associated with trial-and-error learning. This nurturing environment fosters lifelong learning while decreasing the stress associated with education. AI systems can also introduce diversity into the educational process, helping students maintain better focus during learning (108). Furthermore, this technology facilitates opportunities for students to enhance their problem-solving skills and overall learning capacity (109).

In summary, AI offers a myriad of applications for medical students, significantly supporting their development as the key assets of medical universities by helping them to improve their performance and enhance the quality of their learning experience (16, 19, 24, 33, 50).

§ Teaching and Learning Process

The use of AI in higher education leads to the improvement of teaching and learning outcomes. The AI technology enhances student learning by enabling them to confidently use experimental techniques to discover new concepts (110). Another application of AI in the teaching and learning process is the provision of targeted recommendations to students. The AI facilitates a prompt identification of students who are struggling and the provision of timely interventions (111). In addition, the development of adaptive learning approaches through AI significantly enhances student engagement in the learning process and improves their academic progress (112, 113). AI has also enhanced the effectiveness and efficiency of administrative tasks within the educational process. Overall, it plays an important role in improving teaching and learning processes, contributing to the enhancement of educational quality and learning outcomes in the context of medical education (16, 20, 21, 31, 53, 113).

§ Assessment

Advancements in AI have led to significant transformations in student evaluation systems. Online assessment systems have undergone substantial advancements, particularly following the onset of COVID-19 (114). AI can serve various monitoring functions in online examinations, such as tracking the frequency of student pauses during a lesson, the time required to answer a question, and the frequency of trial-and-error attempts for a response (115). AI can also be used for scoring students' written responses or analyzing large and complex datasets (116). Additionally, neural networks can be utilized to design algorithms that help determine whether a student should practice more similar questions or move to higher or lower difficulty levels (111). Machine learning algorithms can also be utilized for various assessment-related tasks, such as monitoring student activities, creating models that accurately predict student outcomes, scoring written responses, and analyzing large and complex datasets (117). As the literature indicates, in the context of medical education, AI offers diverse applications with regard to evaluation systems, from designing personalized questions to providing mechanisms for customizing the evaluation process for each student. This highlights the profound impact of AI on assessment systems and its transformative potential for the future (21, 22, 36, 39, 44).

§ Curriculum

AI inspires innovative ideas in course design and instructional design (118). This technology has diverse applications in medical curricula, such as formulating detailed course objectives, creating content in various formats, generating tailored educational materials for learners with special needs, visualizing course content, producing electronic or digital content, and facilitating the continuous updating of the curriculum content. These significant AI applications substantially enhance the effectiveness and practicality of the curriculum, while facilitating the development of competencies required for the future job market among medical students (18, 32, 50, 54, 71).

§ Management and Implementation

AI technology has a wide range of applications in the managerial and executive aspects of medical education and healthcare. For instance, advanced algorithms can be utilized to predict enrollment rates, dropout rates, and student retention, providing valuable insights for university administrators and policymakers. Additionally, AI supports evidence-based decision-making and policy formulation in the healthcare sector by providing diverse data. A significant advantage of AI in management is its potential for substantial cost reductions across various sectors, as highlighted in several studies (107, 119). In the field of healthcare, AI offers extraordinary applications in several areas,

such as simulation, responsiveness, diagnosis, service quality, and treatment recommendation (23, 29, 48, 57, 72).

Limitations

This study excluded grey literature, such as unpublished reports, theses, and books, which may have limited the scope of findings. The inclusion of these resources in future research could provide a more comprehensive overview of AI applications in medical education.

Conclusion

AI has achieved significant milestones in the field of medical education and is poised to play a pivotal role in its future. However, despite its vast potential, AI presents notable challenges and limitations that must be addressed to ensure its effective integration. This study specifically focused on identifying and categorizing the applications of AI in medical education. Beyond these applications, policymakers and planners must prioritize processes that facilitate the seamless integration of AI technologies into educational frameworks. Adapting to the rapid evolution of AI requires flexible strategies and dynamic forward-looking plans. Developing digital competencies and AI literacy among stakeholders is critical for fostering organizational agility, reducing resistance to technological change, and accelerating adoption. A crucial prerequisite for the successful integration of AI into education is cultural readiness. Policymakers and managers should focus on cultivating collective trust and awareness within institutions to create an environment conducive to AI acceptance. Addressing these factors holistically will enable medical education systems to harness the transformative potential of AI while mitigating its associated challenges.

Authors' Contribution

Each author actively contributed to the discussions, reviewed the content, and approved the final manuscript. They collectively take full responsibility for all aspects of the research, ensuring that any questions or concerns related to the accuracy or integrity of any part of the work are addressed comprehensively and resolved effectively.

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Conflict of Interest

The authors declare no conflicts of interest

Declaration on the use of AI

Artificial intelligence–based language tools were utilized to assist with translation, improve textual structure, and enhance overall clarity during the preparation and editing of this manuscript. All outputs produced by these tools were carefully evaluated, critically revised, and fully approved by the authors.

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