

Original article

Application of artificial intelligence in medical education: A review of benefits, challenges, and solutions

Mahdi Zarei^a, Hamid Eftekhari Mamaghani^b, Amin Abbasi^b and Mohammad-Salar Hosseini^{a,c,*}

^a Research Center for Evidence-Based Medicine, Iranian EBM Center: A JBI Center of Excellence, Tabriz University of Medical Sciences, Tabriz, Iran

^b Student Research Committee, Tabriz University of Medical Sciences, Tabriz, Iran

^c Research Center for Integrative Medicine in Aging, Aging Research Institute, Tabriz University of Medical Sciences, Tabriz, Iran



ARTICLE INFO

Article history:

Received 5 December 2023

Accepted 27 December 2023

Keywords:

AI
Artificial intelligence
Assessment
Medical education
Medical students

A B S T R A C T

Introduction/objectives: Artificial intelligence (AI) holds indisputable potential in solving global challenges faced in healthcare provision, resulting in its ever-increasing utilization in various medical fields. This review aims to present a thorough evaluation of the advantages, challenges, and leading strategies for utilizing AI in the field of medical education.

Methods: In order to access the latest studies and documents, a comprehensive literature search was conducted in Medline (via PubMed), Scopus, and Web of Science databases, using free keywords and MeSH terms representing artificial intelligence, medical education, curriculum, medical student, and their equivalents, without any restriction in time and language, until October 2023.

Results: The expanding integration of AI into medical practice, especially in recent decades, has also led to an increase in the use of different AI methods in medical education. However, integrating AI into medical education comes with advantages and obstacles. The advantages include objective student assessment, better clinical simulation organization, and enhanced education transparency. Conversely, the main challenges of AI integration in education are ethical and legal issues, scalability limitations, evaluating the effectiveness of these educational methods, and technical difficulties.

Conclusions: Further research is needed to specifically identify the potential benefits and challenges, and analyze the proposed solutions for these challenges. Also, the academic curriculum should be evaluated periodically in order to improve the effectiveness of incorporating AI in medical education.

© 2023 The Author(s). Published by Elsevier España, S.L.U. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Aplicación de la inteligencia artificial en la educación médica: una revisión de beneficios, retos y soluciones

R E S U M E N

Introducción/objetivos: La inteligencia artificial (IA) tiene un potencial indiscutible para resolver los desafíos globales que enfrentan en la prestación de servicios de salud, lo que resulta en su utilización cada vez mayor en diversos campos médicos. Esta revisión tiene como objetivo presentar una evaluación exhaustiva de las ventajas, los desafíos y las estrategias líderes para utilizar la IA en el campo de la educación médica.

Métodos: Para acceder a los estudios y documentos más recientes, se realizó una búsqueda bibliográfica exhaustiva en las bases de datos Medline (a través de PubMed), Scopus y Web of Science, utilizando palabras clave gratuitas y términos MeSH que representan inteligencia artificial, educación médica, plan de estudios y estudiantes de medicina, y sus equivalentes, sin restricción alguna de tiempo e idioma, hasta octubre de 2023.

Resultados: La creciente integración de la IA en la práctica médica, especialmente en las últimas décadas, también ha llevado a un aumento en el uso de diferentes métodos de IA en la educación médica. Sin embargo, integrar la IA en la educación médica conlleva ventajas y obstáculos. Las ventajas incluyen evaluación objetiva de los estudiantes, mejor organización de la simulación clínica y mayor transparencia educativa. Por el contrario, los principales desafíos de la integración de la IA en la educación son cuestiones éticas y legales, limitaciones de escalabilidad, evaluación de la efectividad de estos métodos educativos y dificultades técnicas.

Palabras clave:

IA
inteligencia artificial
evaluación
educación médica
estudiantes de medicina

* Corresponding author at: Research Center for Evidence-Based Medicine, Iranian EBM Center: A JBI Center of Excellence, Tabriz University of Medical Sciences, Golgasht Street, Tabriz 51666, EA, Iran.

E-mail address: hosseini.msalar@gmail.com (M.-S. Hosseini).

Conclusiones: Se necesita más investigación para identificar específicamente los beneficios y desafíos potenciales, y analizar las soluciones propuestas para estos desafíos. Además, el currículo académico debe evaluarse periódicamente para mejorar la eficacia de la incorporación de la IA en la educación médica.

© 2023 The Author(s). Publicado por Elsevier España, S.L.U. Este es un artículo Open Access bajo la licencia CC BY-NC-ND (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Introduction

The term artificial intelligence (AI) was first coined by John McCarthy in 1955.¹ But in recent years, with the advent of new algorithms such as machine learning (ML) and its subsets, AI has evolved significantly. Various interpretations of AI have been suggested. One definition describes AI as a machine possessing intelligent capabilities, such as learning, communication, information processing, and induction, that can either perform human functions or aid humans in performing them.² Another definition characterizes AI as the ability of machines to replicate and execute cognitive functions, such as speech and image recognition.³ In essence, AI refers to diverse cognitive models that analyze a vast amount of present data to predict future trends.⁴

AI products play a crucial role in addressing healthcare problems worldwide. The World Health Organization (WHO) recognizes health technologies and AI-based products as vital components of healthcare delivery, ensuring an additional 1 billion patients receive coverage, emergency care, and improved health conditions.⁵ AI can assist healthcare providers in diagnosing ailments, clinical reasoning, data analysis, and making informed clinical decisions.^{6,7} Today, AI-based products extend beyond imaging and pathology-based diagnostic modalities to include various medical fields such as rheumatology, neurology, endocrinology, ophthalmology, orthopedics, and surgery. These fields are also among the most prominent topics of medical research.⁸

Medical education includes various levels, such as undergraduate, postgraduate, specialty, and subspecialty education, also known as continued medical education (CME).⁹ In contrast to the prevalent utilization of AI in medical practice, its usage in medical education was not widely considered until the 1980s.¹⁰ Considering the broad incorporation of AI in different aspects of medical practice, relevant education methods had to be developed and implemented in academic centers. As a result, over the past 40 years, the use of AI in medical education has rapidly expanded, particularly in the last 2 decades, as evidenced by the increasing number of publications in this field.⁸

By analyzing and summarizing large amounts of information, artificial intelligence-based technologies have various applications in medicine and, consequently, in medical education.¹¹ To achieve educational objectives, it is important to comprehensively understand the advantages and disadvantages of incorporating AI in medical education, recognizing that these favorable and unfavorable factors go hand in hand. The aim of this study is to provide a comprehensive and practical review of the benefits, challenges, and leading solutions for the application of AI in medical education.

Methods

A comprehensive literature review was conducted to access the latest studies, literature, and documents from Medline (via PubMed), Scopus, and Web of Science databases, using free keywords and MeSH terms representing artificial intelligence, AI, medical education, and medical students, without any limitation in time or language until October 2023. The Google Scholar engine was also searched to ensure all related documents were included. The records were reviewed and assessed critically according to their consistency with the topic.

Application of artificial intelligence in medical education

Advantages

Integrating AI into medical education offers numerous potential benefits, including improved curriculum design and evaluation and the ability to implement innovative educational methods in clinical settings. This section will review some of the advantages that have made the integration of AI in medical education an undeniable reality.

1. The application of AI in medical education is accompanied by the expansion of the use of virtual reality (VR). VR can transform the future of medical education in various fields, such as anatomy and surgery, by providing innovative, efficient, and cost-effective solutions and leading to the promotion and acceleration of student education.^{12,13}
2. AI can perform formative and summative assessment processes with less time and cost,^{14,15} and by providing feedback to students, it can provide individualized guidance and enrich the learning experience.¹⁶
3. Clinical setting simulators can provide a stress-free educational environment where medical students can practice medical reasoning and learn from their mistakes.¹⁷ These AI-based technologies can enhance students' diagnostic proficiency by 22 percent.¹⁸
4. The use of AI in education increases transparency and allows for a meaningful comparison of the effectiveness of medical education across various countries and institutions. Furthermore, it can potentially motivate individuals and educational departments to take responsibility for their actions.¹⁹
5. Integrating AI into medical education allows for distance learning and makes medical education more accessible in areas with limited resources and remote locations.²⁰ This can significantly benefit newly graduated doctors in providing care. In conditions similar to the COVID-19 pandemic, this advantage prevents a disruption in education and ensures ongoing student-centered learning.²¹
6. Artificial intelligence can facilitate many active learning strategies, such as problem-based, case-based, small-group, and large-group learning.²² This enhances the quality of medical education by identifying the students' needs and making decisions based on them.²³ On the other hand, AI has the potential to allow the sharing of uncommon clinical cases with a larger audience of students, which would otherwise be impossible due to limitations in clinical and academic settings.²⁴
7. AI can offer students the opportunity to learn continuously for 24 hours, even without the active presence of their teachers or educational leaders, using methods like asynchronous learning.²⁵ This kind of learning has the benefit of being adaptable to individual schedules, which is particularly useful for students in clinical years who may have limited time due to work shifts and rounds.²⁶
8. AI has the potential to enhance the assessment of medical students' clinical and diagnostic skills through a comprehensive review of the curriculum. AI-powered techniques not only rely on logistic regression models to evaluate the curriculum but also identify potential challenges and suggest solutions, making them more effective than traditional review methods. For instance, Chen et al. have highlighted how AI-based curriculum reviews can help assess students'

satisfaction and the effectiveness of the curriculum while addressing any obstacles encountered during the process.^{27,28}

9. Financial resource limitation is one of the challenges of medical education, especially in developing countries.²⁹ Artificial intelligence-based technologies can improve the quality of medical education through curriculum reform and the use of innovative teaching strategies and methods cost-effectively.¹⁹

Challenges

As mentioned earlier, the integration of AI in medical education has become more common due to its ability to improve and simplify the learning process. However, the challenges arising from the growing use of AI in medical education must be acknowledged and addressed to prevent the potential benefits from being reduced and becoming a risk.

1. Developing the essential infrastructure and technological framework to support the effective implementation of AI-driven educational methods is difficult, particularly in areas with limited resources.¹⁵ On the other hand, technical challenges and suspension of learning due to AI malfunction would require a significant number of technicians and specialists who have a strong understanding of AI algorithms, such as machine learning, to establish and maintain AI-based education. Providing technical expertise in settings with limited resources can present difficulties.^{11,15,30}
2. The integration of AI into medical education, specifically in clinical and case-based learning, presents ethical challenges. These educational methods involve incorporating vast amounts of patient information into databases and raising concerns about cyber-attacks, patient privacy, confidentiality, and visual security violations. These challenges are among the most significant ones encountered in AI-driven education.^{22,31,32}
3. The lack of a structured curriculum in some medical science fields on one hand, and the absence of a digital medical education curriculum on the other hand, diminishes the possibility of curriculum review and creates challenges in achieving educational goals.^{18,28}
4. One of the benefits of using AI in education is the ability to provide faster feedback to students. However, this approach can have a negative impact on the quality and effectiveness of feedback if it interrupts students' ability to reflect on their learning process.³³
5. A malfunction in AI-based systems can disrupt the learning and evaluation process of students and thus pose challenges in assessing the achievement of educational goals.³⁰
6. The potential of AI to improve the quality of education is acknowledged, although experts have concerns regarding its widespread adoption in medical education due to the potential for increased cheating and plagiarism.^{30,34,35}
7. Challenges in effective interaction with AI-powered learning systems mainly arise from the knowledge gap between physicians/students and system designers. On the other hand, coordinating and overseeing the collaboration between engineers, physicians, and education experts can also be a time-consuming and complex challenge.^{11,15,36}
8. Lack of suitable infrastructure for implementing a student mentoring program in artificial intelligence-based technologies can negatively affect students' educational process and hinder the alignment of the hidden curriculum with educational objectives.^{37,38}
9. The evaluation of AI-based educational strategies is often accompanied by numerous challenges that can hinder awareness of the extent of access to educational goals. Suebnukarn et al. suggest that the best way to evaluate AI-based education methods is to compare them with traditional methods in the same field. However, this approach poses methodological challenges due to the need for large sample sizes, pre- and post-evaluation scoring, and ensuring equal levels of knowledge proficiency. The limited scalability of AI systems is due to their restricted adaptability to their respective fields, as they are only used in a limited range of medical fields (Fig. 1).^{15,39}

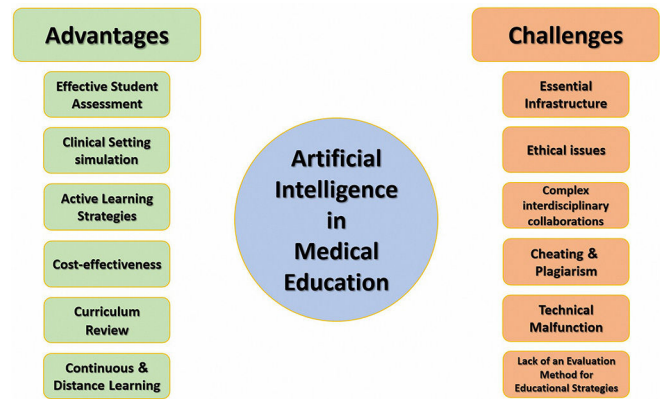


Fig. 1. The advantages and challenges of the application of artificial intelligence in medical education.

Solutions for the practical application of AI in medical education

After understanding the necessity of incorporating artificial intelligence in medical education and evaluating the potential benefits and challenges arising from its integration, it is necessary to determine how this integration can be done efficiently in a way that achieves the goals of medical education, which is the preservation and promotion of health. It is quite clear that the lack of effective integration of artificial intelligence in medical education prevents access to the benefits of its use in medicine and may even have adverse effects on patient care. Therefore, attention to efficient integration is very important.

The model for the application of AI in medical education

The model for AI integration in medical education is based on 3 principles:

1. Introduction to the basic principles of AI, algorithms, and management of AI-based systems in medicine:
The majority of AI functions in the field of medicine rely on statistical principles and formulas. Therefore, in order to effectively use and evaluate these systems in clinical settings, students need to have an understanding of the underlying statistical principles.^{40,41} Once students comprehend these principles, they should be taught about AI algorithms, such as machine learning and its subsets, such as deep learning, random forest, and support vector machines.^{42,43} Additionally, students should gain a practical and theoretical understanding of the utilities, risks, benefits, challenges, and limitations of AI in medicine.^{11,44} To ensure the proper utilization of AI systems, students should also learn about data entry and pattern analysis methods, focusing on preventing bias in data collection.^{45,46} Furthermore, students should be familiarized with how AI influences clinical reasoning and encouraged to actively practice critical and clinical reasoning skills.^{40,42,47,48} Finally, the ultimate goal of AI education should be to teach students how to communicate and share results with patients effectively, compassionately, and productively.^{44,49}
2. Introduction to the ethical and legal implications of using AI in medical facilities:
Students need to know the ethical concerns surrounding the application of AI in the field of medicine. They should also understand the difficulties associated with these concerns and be able to identify the most effective solutions when faced with them in real-life situations.^{42,50} Educational programs should cover ethical issues such as data confidentiality, patient privacy, security, and accountability. This way, students can discuss potential solutions and choose the most suitable ones.^{48,51}
3. Emphasis on teaching pathophysiology and biomedicine science:
Despite recent advances in the design of AI-powered instruments,

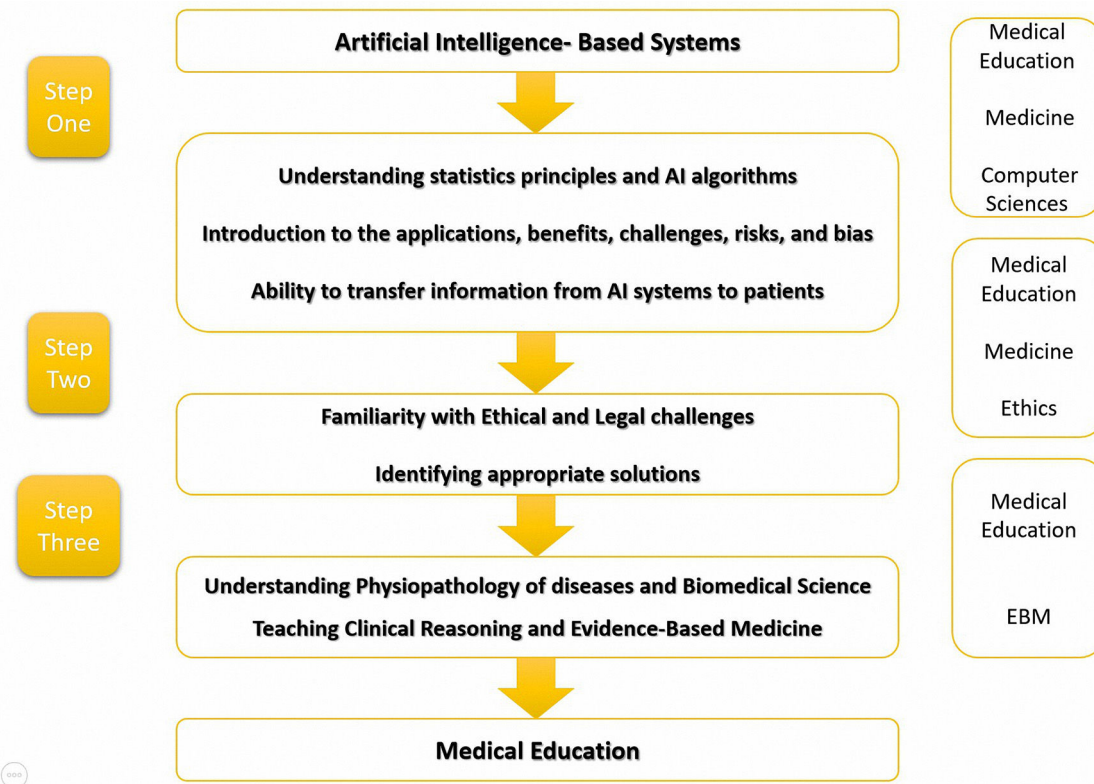


Fig. 2. The stages of the model for the application of artificial intelligence in medical education and interdisciplinary collaborations at each stage. EBM: Evidence-Based Medicine.

the assessment of the decision-making accuracy of these systems largely depends on the inclusion of biomedical sciences and disease pathophysiology in medical education, as they play a role in understanding the foundation of evidence-based medicine (Fig. 2).⁸

Application of artificial intelligence in medical education based on the available evidence

Academic centers worldwide have suggested diverse solutions to tackle the upcoming challenges. These solutions have primarily been introduced as pilot curricula to acquaint students with the multitude of potential uses of artificial intelligence in the field of medicine.

The Toronto School of Medicine has recently begun hosting pre-clinical lectures that focus on introducing students to the use of AI algorithms, such as machine learning, in the field of healthcare. These lectures aim to educate students about the potential applications of artificial intelligence in medicine in the future. Additionally, the university has been actively encouraging the formation of groups interested in exploring the integration of AI in the field of medicine.⁴² The Carle Illinois College of Medicine has proposed enhancing collaboration and interdisciplinary efforts by conducting a course for doctors and engineers to explore the use of AI-based technologies in health-related fields.¹⁹ Duke Institute for Health Innovation has arranged a course aimed at medical students to foster cooperation with data experts and expand their understanding of advanced health technologies.¹⁹ Ulsan and Yonsei universities' medical faculties have also introduced elective courses on artificial intelligence.⁴¹

The significant aspect to consider here is that the solutions are centered around 3 objectives: firstly, enhancing students' understanding of the application of AI in medicine; secondly, highlighting the importance of interdisciplinary collaborations; and thirdly, addressing and resolving the major obstacles faced by AI in medicine and medical education through constructive discussions and dialogs.⁵² Finally, to effectively integrate artificial intelligence into medical education, there is

a need for training specialists, providing suitable artificial intelligence infrastructure, expanding interdisciplinary collaborations, developing appropriate curricula, identifying suitable assessment methods for AI-based teaching strategies, enhancing user and data security, and conducting further studies to identify ethical challenges and existing solutions more than ever before.

Study limitation

This review provides a thorough overview of the application of AI in medical education, highlighting the benefits and challenges it entails. However, it is necessary to recognize certain limitations. The study is constrained by its early stage and the limited research available in this field. While existing literature has been gathered, the number of studies is relatively small, restricting its generalizability. Moreover, the long-term impacts of employing AI models in medical education remain uncertain. Nevertheless, this review offers valuable insights for educators to promote adopting and evaluating artificial intelligence in medical education.

Conclusion

AI has numerous applications in various fields of medicine. The use of these technologies can range from patient triage in emergencies to complex diagnostic and therapeutic procedures. However, until recent decades, little attention has been given to the application of artificial intelligence in medical education. Integrating artificial intelligence in medical education comes with significant advantages and challenges. The benefits and challenges, which need to be further recognized with the increasing use of artificial intelligence, should be given more attention to identifying existing solutions. Alongside the benefits and challenges, the model of integrating artificial intelligence in medical education is also highly important. This model should include training in artificial intelligence algorithms, statistical foundations, managing

these systems in clinical settings, information transfer to patients, consideration of the pathophysiology of diseases and evidence-based medicine, and adherence to ethical principles. Conducting further studies to understand better the advantages and challenges, practical strategies for integrating artificial intelligence in medical education, and identifying future prospects is crucial.

Funding

None.

Data availability statement

All data generated or analyzed during this study are included in this published article.

Declaration of competing interest

None.

Acknowledgments

We appreciate the cooperation of the Clinical Research Development Unit, Imam Reza General Hospital, Tabriz, Iran, in conducting this research.

References

- McCarthy J, Minsky M, Rochester N, Shannon C. A proposal for the Dartmouth summer research project on artificial intelligence, August 31, 1955. *AI Magazine*. 2006;27:12–4.
- Nilsson NJ, Nilsson NJ. *Artificial Intelligence: A New Synthesis*. Morgan Kaufmann; 1998.
- Lee J, Wu AS, Li D, Kulasegaram KM. Artificial intelligence in undergraduate medical education: a scoping review. *Acad Med*. 2021;96(115):S62–70.
- LeCun Y, Bengio Y, Hinton G. Deep learning. *Nature*. 2015;521(7553):436–44.
- Kolachalama VB. Machine learning and pre-medical education. *Artif Intel Med*. 2022;129, 102313.
- Chen J. Playing to our human strengths to prepare medical students for the future. *Kor J Med Educ*. 2017;29(3):193.
- Meskó B, Hetényi G, Györfy Z. Will artificial intelligence solve the human resource crisis in healthcare? *BMC Health Serv Res*. 2018;18(1):1–4.
- Zarei M, Zarei M. Error assessment of artificial intelligence results: what we need to do in medical education. *Strides Dev Med Educ*. 2023;20(1):38–9.
- Bashook PG, Parboosingh J. Continuing medical education: recertification and the maintenance of competence. *BMJ*. 1998;316(7130):545.
- Lillehaug S-I, Lajoie SP. AI in medical education—another grand challenge for medical informatics. *Artif Intel Med*. 1998;12(3):197–225.
- Kolachalama VB, Garg PS. Machine learning and medical education. *NPJ Digit Med*. 2018;1(1):1–3.
- Gan L, Sha C, Wang B. Practice and thoughts of virtual reality technology in medical teaching in China. *Chin J Med Educ Res*. 2019;871–5.
- Pantelidis P, Chorti A, Papagiouvanni I, et al. Virtual and augmented reality in medical education. *Medical and Surgical Education—Past, Present and Future*; 2018. p. 77–97.
- Walkowski S, Lundin M, Szymas J, Lundin J. Exploring viewing behavior data from whole slide images to predict correctness of students' answers during practical exams in oral pathology. *J Pathol Inform*. 2015;6(1):28.
- Chan KS, Zary N. Applications and challenges of implementing artificial intelligence in medical education: integrative review. *JMIR Med Educ*. 2019;5(1):e13930.
- Krstić L, Aleksić V, Krstić M. *Artificial Intelligence in Education: A Review*; 2022.
- Dante A, Marcotullio A, Masotta V, et al. From high-fidelity patient simulators to robotics and artificial intelligence: a discussion paper on new challenges to enhance learning in nursing education. *Methodologies and Intelligent Systems for Technology Enhanced Learning*, 10th International Conference Workshops. 2021: Springer; 2021;Volume 2. p. 111–8.
- McFadden P, Crim A. Comparison of the effectiveness of interactive didactic lecture versus online simulation-based CME programs directed at improving the diagnostic capabilities of primary care practitioners. *J Contin Educ Health Profess*. 2016;36(1):32–7.
- Paranjape K, Schinkel M, Panday RN, Car J, Nanayakkara P. Introducing artificial intelligence training in medical education. *JMIR Med Educ*. 2019;5(2):e16048.
- Kose U. On the intersection of artificial intelligence and distance education. *Artificial Intelligence Applications in Distance Education*. IGI Global; 2015. p. 1–11.
- Gaur U, Majumder MAA, Sa B, Sarkar S, Williams A, Singh K. Challenges and opportunities of preclinical medical education: COVID-19 crisis and beyond. *SN Compr Clin Med*. 2020;2(11):1992–7.
- Wartman SA, Combs CD. Reimagining medical education in the age of AI. *AMA J Ethics*. 2019;21(2):146–52.
- Villegas-Ch W, Arias-Navarrete A, Palacios-Pacheco X. Proposal of an architecture for the integration of a chatbot with artificial intelligence in a smart campus for the improvement of learning. *Sustainability*. 2020;12(4):1500.
- Brasil S, Pascoal C, Francisco R, dos Reis Ferreira VA, Videira P, Valadão G. Artificial intelligence (AI) in rare diseases: is the future brighter? *Genes*. 2019;10(12):978.
- Yuliantoputri AR, Muhamad W, Suhardi S. Smart classroom services system design based on services computing system. 2019 International Conference on ICT for Smart Society (ICISS); 2019. IEEE; 2019. p. 1–6.
- Chen L, Chen P, Lin Z. Artificial intelligence in education: A review. *Ieee Access*. 2020;8:75264–78.
- Chen C-K. Curriculum assessment using artificial neural network and support vector machine modeling approaches: a case study. *IR Applications*. Association for Institutional Research (NJ1); 2010;Volume 29.
- Frehywot S, Vovides Y, Talib Z, et al. E-learning in medical education in resource constrained low-and middle-income countries. *Human Resour Health*. 2013;11(1):1–15.
- Wijk H, Ponzer S, Järnbert-Petersson H, Kihlström L, Nordquist J. Factors related to the role of programme directors in association with quality in postgraduate medical education—a cross-sectional study. *BMC Med Educ*. 2019;19(1):1–9.
- Sarrayrih MA, Ilyas M. Challenges of online exam, performances and problems for online university exam. *Int J Comput Sci Issues (IJCSI)*. 2013;10(1):439.
- Islam G. Informatics Approach to Improving Surgical Skills Training. Arizona State University; 2013.
- Finlayson SG, Bowers JD, Ito J, Zittrain JL, Beam AL, Kohane IS. Adversarial attacks on medical machine learning. *Science*. 2019;363(6433):1287–9.
- Mason BJ, Bruning R. Providing Feedback in Computer-Based Instruction: What the Research Tells Us. Retrieved February 2001. 15; 2007.
- Thorp HH. ChatGPT is Fun, but Not An Author. American Association for the Advancement of Science; 2023. p. 313.
- Cotton DR, Cotton PA, Shipway JR. Chatting and cheating: ensuring academic integrity in the era of ChatGPT. *Innovations in Education and Teaching International*; 2023. p. 1–12.
- Wang JK, Roy SK, Barry M, Chang RT, Bhatt AS. Institutionalizing healthcare hackathons to promote diversity in collaboration in medicine. *BMC Med Educ*. 2018;18(1):1–9.
- Grunhut J, Marques O, Wyatt AT. Needs, challenges, and applications of artificial intelligence in medical education curriculum. *JMIR Med Educ*. 2022;8(2):e35587.
- Zarei M, Bavil FM, Noordoost M. The role of student mentoring in revealing hidden curriculum. *Res Dev*. 2022;11:16.
- Suebnuakarn S, Haddawy P. A Bayesian approach to generating tutorial hints in a collaborative medical problem-based learning system. *Artif Intel Med*. 2006;38(1):5–24.
- Li D, Kulasegaram K, Hodges BD. Why we needn't fear the machines: opportunities for medicine in a machine learning world. *Acad Med*. 2019;94(5):623–5.
- Park SH, Do K-H, Kim S, Park JH, Lim Y-S. What should medical students know about artificial intelligence in medicine? *J Educ Eval Health Professions*. 2019;16.
- McCoy LG, Nagaraj S, Morgado F, Harish V, Das S, Celi LA. What do medical students actually need to know about artificial intelligence? *NPJ Digit Med*. 2020;3(1):1–3.
- Hodges BD. Learning from Dorothy Vaughan: artificial intelligence and the health professions. *Med Educ*. 2018;52(1):11–3.
- Wartman SA. The empirical challenge of 21st-century medical education. *Acad Med*. 2019;94(10):1412–5.
- Lynn LA. Artificial intelligence systems for complex decision-making in acute care medicine: a review. *Patient Safety Surg*. 2019;13(1):1–8.
- Srivastava TK, Waghmare L. Implications of artificial intelligence (AI) on dynamics of medical education and care: a perspective. *J Clin Diagn Res*. 2020;1–2.
- van der Niet AG, Bleakley A. Where medical education meets artificial intelligence: 'Does technology care?'. *Med Educ*. 2021;55(1):30–6.
- Han E-R, Yeo S, Kim M-J, Lee Y-H, Park K-H, Roh H. Medical education trends for future physicians in the era of advanced technology and artificial intelligence: an integrative review. *BMC Med Educ*. 2019;19(1):1–15.
- Wartman SA, Combs CD. Medical education must move from the information age to the age of artificial intelligence. *Acad Med*. 2018;93(8):1107–9.
- Lareyre F, Adam C, Carrier M, Chakfé N, Raffort J. Artificial intelligence for education of vascular surgeons. Elsevier. 2020:870–1.
- Paranjape K, Schinkel M, Nanayakkara P. Short keynote paper: mainstreaming personalized healthcare—transforming healthcare through new era of artificial intelligence. *IEEE J Biomed Health Inform*. 2020;24(7):1860–3.
- Pujol Farriols R, Guanyabens Calvet J. La medicina en tiempos de inteligencia artificial. *Med Clin*. 2023;161(12):530–2.