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Artificial intelligence in current undergraduate medical education

La inteligencia artificial en la educación médica de pregrado actual

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SUMMARY

Artificial intelligence is a rapidly growing phenomenon poised to instigate large-scale changes in medicine. With emerging innovations in artificial intelligence poised to impact medical practice substantially, interest in training current and future physicians about the technology is growing. Alongside comes the question of what medical students should be taught. While competencies for the clinical usage of Artificial intelligence are broadly similar to those for any other novel technology, they are critical to concerns regarding ethical aspects, health equity, and data security. The update should equate future physicians with the knowledge and skills to effectively use artificial intelligence applications and ensure that professional values and rights are protected. Artificial intelligence has the potential to revolutionize the domain of medicine, particularly in current undergraduate medical education. Ready or not, undergraduate medical education is undergoing a massive transformation driven by artificial intelligence. However, medical schools still need to start teaching about artificial intelligence.

Keywords: *Artificial intelligence, undergraduate medical education, emerging technological innovations, ChatGPT.*

RESUMEN

La inteligencia artificial es un fenómeno en rápido crecimiento que está iniciando cambios a gran escala en la medicina. Con las innovaciones emergentes en inteligencia artificial influyendo sustancialmente en la práctica médica, crece el interés por formar a los médicos actuales y futuros en esta tecnología. Al mismo tiempo, se plantea la cuestión de qué se debe enseñar a los estudiantes de medicina. Aunque las competencias para el uso clínico de la inteligencia artificial son muy similares a las de cualquier otra tecnología novedosa, existen diferencias cualitativas de importancia crítica para las preocupaciones relativas a los aspectos éticos, la equidad médica y la seguridad de los datos. La actualización debe girar en torno a dotar a los futuros médicos de los conocimientos y habilidades necesarios para utilizar eficazmente las aplicaciones de la inteligencia artificial y garantizar la protección

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de los valores y derechos profesionales. La inteligencia artificial tiene el potencial de revolucionar el ámbito de la medicina, sobre todo en la actual formación médica de pregrado. Preparada o no, la educación médica de pregrado está experimentando una transformación masiva impulsada por la inteligencia artificial. Pero las facultades de medicina apenas han empezado a enseñar sobre inteligencia artificial.

Palabras clave: *Inteligencia artificial, educación médica de pregrado, innovaciones tecnológicas emergentes, ChatGPT.*

INTRODUCTION

Artificial intelligence (AI) has recently made significant progress in many applications, including medicine.

There is no generally accepted definition of Artificial intelligence (AI). Numerous different ones are used, and this can easily lead to confusion. In its strictest definition, AI is the imitation by computers of the intelligence inherent in humans. Nevertheless, we need a definition that captures the whole range of applications finding their way into practice today and in the near future. The definition of the High-Level Expert Group on Artificial Intelligence provides the necessary freedom of scope. Describing AI as "systems that display intelligent behavior by analyzing their environment and taking actions with some degree of autonomy to achieve specific goals," this encompasses all the applications we currently qualify as AI and, at the same time, provides scope for future changes to that qualification (1). International Business Machines (IBM) defines AI as "a field which combines computer science and robust datasets to enable problem-solving." Artificial intelligence (AI) is the multidisciplinary approach of computer science and linguistics that aspires to create machines capable of performing tasks that usually require human intelligence (2). These tasks include the ability to learn, adapt, rationalize, understand, and fathom abstract concepts as well as the reactivity to complex human attributes such as attention, emotion, creativity, etc. (3). The subfield of AI that may be most relevant for medicine is machine learning, in which algorithms typically find patterns in provided data to classify items or identify subgroups within the data set.

AI is not new; its lineage can be traced to artificial neural networks dating to the late 1950s. Alan Turing began his paper Computing Machinery and Intelligence by asking whether machines can think? In 1959, he was the first scientist to question this, although he did not coin the term we know today as artificial intelligence (4). In 1956, a group of academics spanning computer science, mathematics, linguistics, psychology, and other fields came together to discuss ideas under the umbrella of a field they coined "artificial intelligence". Since then, the approaches evolved from the foundational AI algorithms of the 1950s to the paradigm shift in symbolic algorithms and expert system development in the 1970s, the introduction of machine learning in the 1990s, and the deep learning algorithms of the 2010s. In the late 2010s and early 2020s, models like GPT (Generative Pre-training Transformer) significantly improved AI development. Today, AI broadly represents the field of study concerned with developing machines that can reason and perform cognitive functions that approximate those of humans (5-7).

The first medical system that exhibited what many would call AI capabilities was MYCIN, a system for treating blood infections developed by Edward Shortliffe and colleagues at Stanford University (8). INTERNIST-I, a rule-based computer diagnostic system developed in the 1970s based on the expertise of a single clinician at the University of Pittsburgh, was another notable advance (6). Medical AI tools have since evolved to incorporate more complex methods, such as deep learning, that have yielded automated preliminary reads in diagnostic radiology and pathology and advanced surgical guidance systems (9,10,11,12). Modern perceptions and expectations of AI have been mainly influenced by advances in deep learning techniques over the last decade (2,13,14). With these advances, there has been a proliferation of tools, including AI voice assistants (e.g., Apple's Siri, Amazon's Alexa), natural language processing assistants (e.g., Grammarly), and speech recognition tools (e.g., Nuance's Dragon). As data sets have grown and processors have become more powerful, scientists have become more adept and creative at leveraging them to create more impressive AI tools.

The proper functioning of AI is primarily subordinated to the algorithms and processes used to develop it. In this sense, AI systems can be weak, robust or super. In the case of weak AI, it is a system designed and trained to perform a single task. On the other hand, strong AI is a system with cognitive abilities similar to humans, allowing it to find the solution to a given task independently. Finally, artificial superintelligence is the stage of AI when the capability of computers surpasses that of human beings. This stage is currently a hypothetical situation.

As AI tools have become ubiquitous and have subtly begun to permeate many aspects of our daily lives in ways both seen and unseen, the goalposts for what individuals consider AI have shifted. Artificial intelligence (AI) is a rapidly growing phenomenon poised to instigate large-scale changes in medicine. However, medical education has yet to keep pace with the rapid advancements of AI (15,16). Despite several calls to action, the adoption of teaching AI in undergraduate medical education has been limited. This paper aims to briefly review the current state of artificial intelligence in undergraduate medical education.

Scoping Artificial intelligence to undergraduate medical students

Artificial intelligence tools are embedded in nearly every facet of life, whether we recognize or define them explicitly as "AI." Every popular search engine and web browser uses AI, social media and entertainment applications use AI, our cellular telephones use AI, and our electronic medical records systems use AI. Therefore, it would be prudent for medical educators to consider safeguards to encourage the appropriate, safe use of AI tools and to avoid their improper use. As a result of the fast growth of AI applications in many fields, in recent years, the interest in integrating AI education into medical school curricula has flourished considerably and has been correspondingly sustained by literature. As AI is progressively used in healthcare, undergraduate medical students must understand its principles and potential applications (17).

Recent literature has highlighted the potential of AI in medical education, particularly in helping undergraduate medical student with complex medical concepts and improving their clinical reasoning skills. Various studies have insisted on the critical role of implementing AI education in medical studies, and several authors, having analyzed the current landscape of medical education, assessed the ineffectiveness of medical curricula in integrating proper AI training. Nonetheless, AI literacy is far from widespread among medical students and faculty. Despite the potential benefits of AI over traditional methods, its implementation in curriculum reviews needs to be more present. One possible explanation for this is the insufficient level of digitalization within medical education's learning management systems, which is necessary to develop a comprehensive curriculum map (16,18).

Moreover, medical students seem to need more basic scientific knowledge correlated to the role of AI in their professional environment. Although clinicians are asked to master and develop their understanding of AI in health care, medical education fails to provide such skills (19). Undergraduate medical students are particularly aware of AI's growing role in medical education and have expressed the need to be more educated about its potential and applications in medical practice (20-22). In 2022, a study highlighted the need for future physicians to become more familiar with AI and proved that they would become better physicians with the widespread use and knowledge of AI. It shows that undergraduate medical students need adequate training on AI in medicine, even if predominantly favorable to structured training on AI applications during medical education (20). In medicine, AI is on the precipice of instigating large-scale changes that will transform how health care is delivered, the tools used by health care professionals, and the traditional roles of patients and health care professionals (23).

With the advent of new technologies and medical discoveries, expanding medical information increased the difficulty for medical students and physicians to keep pace (14). Artificial intelligence can organize and merge considerable volumes of data and perfect the decision-making process of medical students and physicians, thus simplifying the path leading to diagnosis identification and recommended treatments (14,17,24,25). Recent literature

endorsed the role of AI and machine-learning predictive algorithms as extremely advantageous catalyzers and fast analyzers of clinical data; these tools represent the keys to unlocking the data capable of informing real-time decisions (26). Predictive algorithms are already used to avert hospitalization for patients with low-risk pulmonary embolisms and prioritize patients for liver transplantation (27). In the future, deep learning is expected to be utilized by a wide range of clinicians and specialty doctors (25). The implementation of AI tools has been discussed, tested, and/or adopted in several medical areas, such as histopathology (28-31) and cancer prevention (28,32-34).

AI will continue to transform medical education drastically in the following decades. To respond to the changing landscape of medicine and train effective medical practitioners, academic education must adapt and reform its curriculum, incorporating teaching AI (35). Based on existing literature, three main issues have been identified in present medical education: firstly, AI is not widespread as an educational subject in any medical education linked curricula; secondly, undergraduate medical students lack the basic scientific knowledge related to the role of AI in their professional environment; thirdly, medical professors are inadequately sensitized and trained about AI, thus preventing the patient from receiving AI improved care.

Subsequently, AI programs in medical education internationally should include the following elements: 1) solve the lack of AI education in the medical field; 2) sensibilize undergraduate medical students, who will be future medical doctors in the field of new technologies applied to medicine; 3) consider the lack of students' prior scientific knowledge, which is necessary to approach AI learning (36,37).

Numerous factors may have contributed to the lack of consensus regarding AI curricular content and delivery: 1.- lack of AI integration efforts due to the barriers identified from current studies, 2- AI is a relatively new field with remarkable advances made within the last ten years medical educators may not simply had enough time to appreciate how AI will impact health care delivery and thus undergraduate medical education, and 3.- the complexity of integrating AI curricula working in AI-integrated health care requires complex skill sets that include AI-specific competencies along with improvements in non AI domains such as skills of caring (i.e., empathy and communication) (38,39).

Required artificial intelligence´s enclosure in undergraduate medical education curricula

New emerging technologies raise numerous questions about the future of medicine and the role of medical doctors. Despite increasing interest in new technology, medical education has yet to keep pace with the remarkable breakthroughs made in AI. There have been several calls to action, but the adoption of AI training into undergraduate medical education has been limited, perhaps due to the need for more systematic evidence. As the adoption of AI continues to grow in health care, integration in undergraduate medical education will offer substantial benefits for future practice since undergraduate medical education can reach the largest group of medical trainees early in their careers. Understanding how AI should be taught and integrated into undergraduate medical education curricula should be guided by the best available scholarly evidence (6,9,13).

The sharing of knowledge about AI, integrating AI tools into existing curricula, and creating specialized curricula emphasizing AI utilization as a competency warrant careful consideration, as clinicians and patients alike would benefit from a greater understanding of AI's benefits and risks (10,14,16).

AI has the potential to have significant and wide-sweeping impacts on medicine. Medical education must prepare learners for these potential changes. Ungraduated medical students have a potentially unique role in AI training and medicine as it allows for early exposure and integration of AI into medical education and can reach the broadest medical learner population. AI has been widely recognized as one of medical education's most transformative and ground-breaking technological advancements. From disease diagnosis to drug development, AI has successfully proven its efficacy in numerous modern-day medicines, but its adoption has yet to be improved (17,18,30). The effectiveness of AI-powered technologies in medical education relies

heavily on the participation of medical professors in creating and testing these technologies (35,37).

Consequently, medical education is also transforming, with AI being integrated into various aspects of the curricula of undergraduate medical students (36). More research is needed to fully understand the knowledge and attitudes of medical students towards AI and its applications in medical education and practice. However, the current landscape of medical education does not adequately prepare medical students for the potential of AI in healthcare. As AI applications become more widespread in the medical field, it is crucial to understand how ungraduated medical students and future medical doctors perceive and interact with these new technologies. Despite the increasing use of AI in medicine, research on the knowledge and attitudes of ungraduated medical students towards AI still needs to be completed. Several factors may influence medical students' perspectives, including their level of exposure to AI in medical education, their understanding of the advantages and disadvantages of AI, and their career aspirations (10,11).

ChatGPT and the future of medical education

Artificial intelligence (AI) systems can process limitless amounts of information and provide personalized experiences with the potential to revolutionize how medical students learn. One AI technology, ChatGPT (Generative Pre-trained Transformer), has generated much excitement in medical education and is poised to make a significant impact (40,41). Launched in November 2022, "ChatGPT" is an AI-based large language model trained on massive text data sets in multiple languages with the capacity to generate human-like responses to text input. Developed by Open AI, L.L.C., San Francisco, CA, USA), ChatGPT etymology is related to being a chatbot (a program able to understand and generate responses using a text-based interface). It is based on the generative pre-trained transformer (GPT) architecture (40,42).

Once trained, ChatGPT can generate text in response to user input by leveraging its learned language knowledge. When a user enters a prompt or a question, ChatGPT processes the input and generates a response based on its understanding of the context and the language. The GPT architecture utilizes a neural network to process natural language, thus generating responses based on the context of input text. The superiority of ChatGPT compared to its GPT-based predecessors can be linked to its ability to respond to multiple languages, generating refined and highly sophisticated responses based on advanced modeling (42).

In the scientific community and academia, ChatGPT has received mixed responses reflecting the history of controversy regarding the benefits against risks of advanced AI technologies (43,44). On the one hand, ChatGPT, among other large language models, can be beneficial in conversational and writing tasks, assisting in increasing the efficiency and accuracy of the required output. On the other hand, concerns have been raised about possible bias based on the datasets used in ChatGPT training, which can limit its capabilities and result in factual inaccuracies but alarmingly appear scientifically believable. Security concerns and the potential of cyber-attacks with the spread of misinformation utilizing large language models should also be considered (45). In the area of medical education, ChatGPT has considerable transformative potential. The need to rethink and revise the current assessment tools in medical education comes from considering ChatGPT's ability to pass reputable exams (e.g., USMLE) and the possibility of ChatGPT misuse, which would result in academic dishonesty (46-48).

AI is increasing and becoming popular in many medical fields, including ophthalmology, dermatology, pathology, and others. Specifically, an ophthalmology examination showed that ChatGPT is currently performed at the level of an average first-year resident (49). Such a result highlights the need to focus on questions involving the assessment of critical and problem-based thinking. Additionally, the utility of ChatGPT in medical education can involve tailoring education based on the needs of the student with immediate feedback (50). Thus, ChatGPT can be helpful in medical education, including enhanced communication skills, given proper academic mentoring (51,52). However, the copyright issues regarding the ChatGPT-generated clinical vignettes should be considered, aside from the issue of incorrect references.

Additionally, ChatGPT availability can be viewed as a motivation in medical education based on the personalized interaction it provides, enabling powerful self-learning and its utility as an adjunct in group learning (53,54).

Other limitations of ChatGPT use in medical education include the concern regarding the quality of training data sets that could result in biased content and inexact information limited to the period before 2021 (since ChatGPT was launched in November 2022). Furthermore, other concerns include the current inability of ChatGPT to handle images, its low performance in some topics, and the issue of possible plagiarism. Despite ChatGPT's usefulness in academic education, the content of ChatGPT in research assignments was discouraged, needing to be revised, biased, or misleading (46,47).

ChatGPT, as an example of another large language model, can be described as a promising or even a revolutionary tool for scientific research in both academic writing and the research process itself. Specifically, ChatGPT was listed in several sources as an efficient and promising tool for conducting comprehensive literature reviews and generating computer codes, thereby saving time for the research steps that require more effort from human intelligence (e.g., the focus on experimental design) (50,55,56). Additionally, ChatGPT can help generate queries for comprehensive systematic review with high precision, despite the authors highlighting the transparency issues and unsuitability for high-recall retrieval. Moreover, the utility of ChatGPT extends to involve an improvement in language and a better ability to express and communicate research ideas and results, ultimately speeding up the publication process with the faster availability of research results (57,58).

ChatGPT trains its neural network using an unsupervised learning algorithm. Unsupervised learning is a type of machine learning in which the model is presented with unlabeled data and must find patterns and relationships within the data on its own. The specific algorithm used to train ChatGPT is called transformer architecture. It was first introduced in 2017 and has since become the state-of-the-art for many natural language processing tasks (52,53,57).

With ChatGPT, students can easily and quickly look up information on any topic, allowing them to understand complex concepts better. Another key benefit of using ChatGPT in medical education is that it can provide personalized learning experiences. ChatGPT can analyze data on a student's learning style, strengths, and weaknesses and provide tailored learning experiences optimized for their individual needs. Teaching students how to make informed clinical decisions is one of the biggest challenges in medical education. With ChatGPT, medical students can receive real-time feedback on their decision-making processes and learn from the experiences of others. This can help improve their critical thinking skills and equip them with the knowledge and confidence to make effective clinical decisions once they enter the workforce (55,57,59).

The ability of ChatGPT to help streamline the clinical workflow appears promising, with possible cost savings and increased efficiency in health care delivery. ChatGPT, among other large language models, can have a transforming potential in health care practice via enhancing diagnostics, disease risk and outcome prediction, and drug discovery, among other areas in translational research (59,60). Moreover, ChatGPT showed moderate accuracy in determining the imaging steps needed in breast cancer screening and the evaluation of breast pain, which can be a promising application in decision-making in radiology. ChatGPT in health care settings also has the prospects of refining personalized medicine and improving health literacy by providing easily accessible and understandable health information to the general public.

ChatGPT responses demonstrated this utility, highlighting the need to consult health care providers and other reliable sources on specific situations (61,62).

Perhaps the most popular advance in AI as of 2023 has been in the space of large language models (LLMs). LLMs are deep learning algorithms that recognize, predict, and generate text, images, and other content. Two tools using this approach are BERT (Bidirectional Encoder Representations from Transformers) and GPT

(Generative Pre-trained Transformer), first introduced by Google and Open AI, respectively, in 2018, with ChatGPT released by Open AI to the lay public via a chat interface in 2022. These AI tools leverage enormous amounts of training data from datasets scraped from the Internet and use this training to generate responses to queries or prompts posed in natural language (as opposed to requests made in computer code). They create responses to the questions by considering their training data and generating statistically likely sequences of words that would fulfill the query. While the specific architectures of the most popular LLMs are proprietary, the predominant training technique for these models is known as reinforcement learning from human feedback (RLHF). Reinforcement learning is a machine learning technique akin to operant conditioning, where an algorithm receives mathematical positive or negative rewards based on its task performance. With RLHF, a human provides feedback to the algorithm by ranking its responses, thus introducing human preferences into the algorithm's reward structure (63). This training process allows LLMs to generate complex text answers that may seem to have been written by a human. One of the limitations of the current generation of LLMs is that small changes in prompt structure can yield vastly different responses. To refine the responses to achieve the desired output, users can engage in fast engineering, which refers to crafting prompts to optimize the performance of LLMs in generating accurate, contextually relevant responses. LLM-generated text is based on the statistical associations of patterns of words to the patterns seen in training data and prompts (64).

Although ChatGPT has the potential to revolutionize medical education, it is essential to note that AI technology cannot replace human expertise and judgment. Experienced practitioners must still train medical students to develop their clinical skills and gain a deep understanding of the field. ChatGPT cannot replace the hands-on experience and mentorship essential for practical medical training (54,56,58,61).

Among the most popular AI alternatives to ChatGPT are:

1) YouChat, which is constantly updated with the latest information from the Internet, so it offers the most current answers possible. ChatGPT has a much more versatile menu: it contains a section for the chat itself, another for images and videos, and one for managing and promoting profiles on social networks. In addition, it is much more accessible than the rest of chatbots since it has a QR code on its website that allows you to chat directly with the AI through WhatsApp. It is much more practical and faster to use.

2) Perplexity: It has in common with ChatGPT that the same OpenAI engine has trained them, so it can offer answers according to what is being asked and is much more personalized. What makes this AI different is the construction of documented texts. In other words, while it elaborates on an answer, it cites the sources on which it is based. This is an excellent advantage as it allows us to verify that the information provided is reliable.

3) Chatsonic: This chat can be, without a doubt, the best alternative to ChatGPT since it provides search results on the most current topics possible, thanks to Google. ChatSonic presents excellent potential thanks to the fact that the platform allows specialized searches, obtaining summaries, and training writing, thanks to the instructions provided to the AI itself. Another aspect to consider is that the generated answers can be shared as PDF documents or through links.

4) BingChat is Microsoft's search engine. From the moment you enter its website, you can train its AI by choosing the tone of the conversation: whether you want a more creative, precise, or neutral tone. Another big plus is that Dall-e is integrated into this chatbot. It is the Artificial Intelligence that can create images from the directives given to the chat.

5) Google Bard is the AI system created by Google. It allows users to interact by exchanging messages. It is based on a powerful experimental language created exclusively by Google, LaMDA (65).

Among many other leading applications of AI in Undergraduate Medical Education are:

1. Diagnostic Support: One of the primary applications of AI in medical education is diagnostic support.

2. Virtual Patient Simulations: AI-powered virtual patient simulations offer a valuable learning tool for medical students.
3. Personalized Learning: AI technologies can adapt educational content to individual student needs, enabling personalized learning experiences.
4. Natural Language Processing (NLP): NLP is a branch of AI that focuses on understanding human language.
5. Clinical Decision Support Systems: AI-powered clinical decision support systems can assist medical students in making evidence-based treatment decisions.

DISCUSSION

Undergraduate medical education is experiencing a considerable transformation driven by artificial intelligence. With emerging innovations in artificial intelligence (AI) poised to substantially impact medical practice, interest in training current and future physicians about the technology is growing. The update should equate future physicians with the knowledge and skills to effectively use AI applications and ensure that professional values and rights are protected (6,9,14,16).

Despite the large volume of literature, there is little consensus on what and how to teach AI to ungraduated medical students (for example, this search with the specific keyword "Artificial intelligence in current undergraduate medical education" performed in Google Academic on October 13, 2023, over 113 000 results were found). As AI applications become more widespread in the medical field, it is crucial to understand how ungraduated medical students and future medical doctors perceive and interact with these new technologies. Despite the increasing use of AI in medicine, research on the knowledge and attitudes of ungraduated medical students towards AI still needs to be completed. Several factors may influence medical students' perspectives, including their level of exposure to AI in medical education, their understanding of the advantages and disadvantages of AI, and their career aspirations (2,6,16).

The need to integrate AI into medical education has been abundantly discussed. Literature shows that medical students need more knowledge about AI and its applications in clinical practice during their academic education. However, medical schools still need to start teaching about AI (19,20).

It is necessary to regulate the design, development, and implementation of AI and its products, to establish a code of ethics for the prevention of malpractice and overreach in the use of technologies, to expressly prohibit the use of weapons, the use of personal data, the application of abusive clauses and to limit the scope of the dominant perspective in interactions with living beings. Likewise, freedom and autonomy must be maintained as exclusive characteristics of human beings and subject to permanent control. Its operability must be parameterized within the respect for life, dignity, justice, equity, non-discrimination, peace, and the prohibition of monopoly in the praxis of sciences, disciplines, occupations, or trades (66,67). To limit the risks and maximize the opportunities intrinsic to the use of AI for health, WHO (World Health Organization) provides the following principles as the basis for AI regulation and governance: Protecting human autonomy, promoting human well-being and safety, and public interest, ensuring transparency, explainability, and intelligibility, Fostering responsibility and accountability, Ensuring inclusiveness and equity. Promoting AI that is responsive and sustainable (68). AI should not become a strategy of academic fraud but a formative complement.

Although the use of AI is widely spread worldwide, in the case of university education in Venezuela, the use of AI is a little-known topic and is sometimes plagued by misinformation. More evidence of the impact of AI on Venezuelan education needs to be provided. In addition to the digital and social gap, since AI is a relatively new technology and a large majority of the Venezuelan population does not have access to it due to failures in public services such as electricity, lack of internet, and the socioeconomic conditions of students and teachers (69,70). The need for more specific reference sources on AI in the Venezuelan educational system makes it difficult to obtain data and empirical evidence to support an analysis (71).

In addition, ChatGPT's (Generative Pre-trained Transformer) main AI technology is not accessible or available nowadays in Venezuela. However, other AI applications are available with possible limitations.

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Conflicts of Interest

The author declares no conflict of interest.

REFERENCES

1. Sheikh H, Prins C, Schrijvers E. Artificial Intelligence: Definition and Background. In: Mission AI. Research for Policy. Springer, Cham. 2023.p.15-41.
2. Carin L. On Artificial Intelligence and Deep Learning Within Medical Education. Acad Med. 2020;95(11S):S10-S11.
3. CK, Gin B, Golde PB, Hauer KE. ChatGPT and Generative Artificial Intelligence for Medical Education: Potential Impact and Opportunity. Acad Med. 2024;99(1):22-27.
4. Turing A. Computing Machinery and Intelligence. Mind, New Series. Oxford University Press on behalf of the Mind Association. 1950;59(236):433-460.
5. Buchanan B. A (Very) Brief History of Artificial Intelligence. Association for the Advancement of Artificial Intelligence. AI Magazine. 2006;26(4):53-60.
6. Jiang F, Jiang Y, Zhi H, Dong Y, Li H, Ma S, et al. Artificial intelligence in healthcare: past, present and future. Stroke Vasc Neurol. 2017;2(4):230-243.
7. Oniani D, Hilsman J, Peng Y, Poropatich RK, Pamplin JC, Legault GL, et al. Adopting and expanding ethical principles for generative artificial intelligence from military to healthcare. NPJ Digit Med. 2023;6(1):225.
8. Shortliffe E. Feature Interview: Edward H. Shortliffe on the MYCIN Expert System. Computer Compacts. Elsevier, New York, USA. 1976;(1):283.
9. El Naqa I, Haider MA, Giger ML, Ten Haken RK. Artificial Intelligence: Reshaping the practice of radiological sciences in the 21st century. Br J Radiol. 2020;93(1106):20190855.
10. Davenport T, Kalakota R. The potential for artificial intelligence in healthcare. Future Healthc J. 2019;6(2):94-98.
11. Amisha M, Malik P, Pathania M, Rathaur VK. Overview of artificial intelligence in medicine. J Family Med Prim Care. 2019;8(7):2328-2331.
12. Yazdani A, Costa S, Kroon B, Artificial intelligence: Friend or foe? Australian and New Zealand J Obstet Gynaecol. 2023;(63):2:127-130.
13. Buch VH, Ahmed I, Maruthappu M. Artificial intelligence in medicine: Current trends and future possibilities. Br J Gen Pract. 2018;68(668):143-144.
14. Paranjape K, Schinkel M, Nannan Panday R, Car J, Nanayakkara P. Introducing Artificial Intelligence Training in Medical Education. JMIR Med Educ. 2019;5(2):e16048.
15. Hogarty DT, Su JC, Phan K, Attia M, Hossny M, Nahavandi S, et al. Artificial Intelligence in Dermatology-Where We Are and the Way to the Future: A Review. Am J Clin Dermatol. 2020;21(1):41-47.
16. Chan KS, Zary N. Applications and Challenges of Implementing Artificial Intelligence in Medical Education: Integrative Review. JMIR Med Educ. 2019;5(1):e13930.
17. Briganti G. Intelligence artificielle : une introduction pour les cliniciens [Artificial intelligence: An introduction for clinicians]. Rev Mal Respir. 2023;40(4):308-313.
18. Agrebi S, Larbi A. Use of artificial intelligence in infectious diseases. Artificial Intelligence in Precision Health. 2020:415-438.

19. Sapci AH, Sapci HA. Artificial Intelligence Education and Tools for Medical and Health Informatics Students: Systematic Review. JMIR Med Educ. 2020;6(1):e19285.
20. Civaner MM, Uncu Y, Bulut F, Chalil EG, Tatli A. Artificial intelligence in medical education: A cross-sectional needs assessment. BMC Med Educ. 2022;22(1):772.
21. Frommeyer TC, Fursmidt RM, Gilbert MM, Bett ES. The Desire of Medical Students to Integrate Artificial Intelligence into Medical Education: An Opinion Article. Front Digit Health. 2022;(4):831123.
22. Zhong JY, Fischer NL. Commentary: The desire of medical students to integrate artificial intelligence into medical education: An opinion article. Front Digit Health. 2023;(5):1151390.
23. Park Y, Jackson GP, Foreman MA, Gruen D, Hu J, Das AK. Evaluating artificial intelligence in medicine: Phases of clinical research. JAMIA Open. 2020;8(3):326-331.
24. Coppola F, Faggioni L, Gabelloni M, De Vietro F, Mendola V, Cattabriga A, et al. Human, All Too Human? An All-Around Appraisal of the "Artificial Intelligence Revolution" in Medical Imaging. Front Psychol. 2021;(12):710982.
25. Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. Nat Med. 2019;25(1):44-56.
26. Agrebi S, Larbi A. Use of artificial intelligence in infectious diseases. Artificial Intelligence in Precision Health. 2020:415-438.
27. Chen JH, Asch SM. Machine Learning and Prediction in Medicine - Beyond the Peak of Inflated Expectations. N Engl J Med. 2017;376(26):2507-2509.
28. Saldanha OL, Quirke P, West NP, James JA, Loughrey MB, Grabsch HI, et al. Swarm learning for decentralized artificial intelligence in cancer histopathology. Nature Medicine. 2022;28(6):1232-1239.
29. Attallah O. MB-AI-His: Histopathological Diagnosis of Pediatric Medulloblastoma and its Subtypes via AI. Diagnostics. 2021;11(2):359.
30. Shmatko A, Ghaffari Laleh N, Gerstung M, Kather JN. Artificial intelligence in histopathology: Enhancing cancer research and clinical oncology. Nat Cancer. 2022;(3):1026-1038.
31. Abdelsamea M, Zidan U, Senousy Z, Gaber M, Rakha E, Ilyas, M. A survey on artificial intelligence in histopathology image analysis. WIREs Data Mining and Knowledge Discovery. 2022;12(6):e1474.
32. Ray A, Bhardwaj A, Malik YK, Singh S, Gupta R. Artificial intelligence and Psychiatry: An overview. Asian J Psychiatr. 2022;(70):103021.
33. Byng D, Strauch B, Gnas L, Leibig C, Stephan O, Bunk S, et al. AI-based prevention of interval cancers in a national mammography screening program. Eur J Radiol. 2022;152:110321.
34. Shmatko A, Ghaffari Laleh N, Gerstung M, Kather JN. Artificial intelligence in histopathology: Enhancing cancer research and clinical oncology. Nat Cancer. 2022;3(9):1026-1038.
35. Wartman SA, Combs CD. Medical Education Must Move from the Information Age to the Age of Artificial Intelligence. Acad Med. 2018;93(8):1107-1109.
36. Briganti G, Pizzolla I. Data from: Integrating Artificial Intelligence into Medical Education: Lessons Learned from a Belgian Initiative. J Interactive Learning Research. 2023;34(2):401-424.
37. Hashimoto DA, Johnson KB. The Use of Artificial Intelligence Tools to Prepare Medical School Applications. Acad Med. 2023;98(9):978-982.
38. Sallam M. ChatGPT Utility in Healthcare Education, Research, and Practice: Systematic Review on the Promising Perspectives and Valid Concerns. Healthcare. 2023;11(6):887.
39. Law M, Veinot P, Campbell J, Craig M, Mylopoulos M. Computing for Medicine: Can We Prepare Medical Students for the Future? Acad Med. 2019;94(3):353-357.
40. Arif TB, Munaf U, Ul-Haque I. The future of medical education and research: Is ChatGPT a blessing or blight in disguise? Med Educ Online. 2023;28(1):2181052.
41. Varma JR, Fernando S, Ting BY, Aamir S, Sivaprakasam R. The Global Use of Artificial Intelligence in the Undergraduate Medical Curriculum: A Systematic Review. Cureus. 2023;15(5): e39701.
42. Brown T, Mann B, Ryder N, Subbiah M, Kaplan J, Dhariwal P, et al. Language models are few-shot learners. Advances in neural information processing systems. 2020;(33):1877-1901.
43. Howard J. Artificial intelligence: Implications for the future of work. Am J Ind Med. 2019;62(11):917-926.
44. Tai MC. The impact of artificial intelligence on human society and bioethics. Tzu Chi Med J. 2020;32(4):339-343.
45. Deng J, Lin Y. The Benefits and Challenges of ChatGPT: An Overview. Frontiers in Computing and Intelligent Systems. 2023;2(2):81-83.
46. Sallam M, Salim NA, Barakat M, Al-Mahzoum K, Al-Tammemi AB, Malaeb D, et al. Assessing Health Students' Attitudes and Usage of ChatGPT in Jordan: Validation Study. JMIR Med Educ. 2023;9:e48254.
47. Duong D, Solomon BD. Analysis of large-language model versus human performance for genetics questions. European J Human Genetics. 2023. https://doi.org/10.1038/s41431-023-01396-8

48. Bašić Ž, Banovac A, Kružić I, Jerković I. ChatGPT-3.5 as writing assistance in students' essays. Humanit Soc Sci Commun. 2023;(10):750.
49. Huh S. Issues in the 3rd year of the COVID-19 pandemic, including computer-based testing, study design, ChatGPT, journal metrics, and appreciation to reviewers. J Educ Eval Health Prof. 2023;(20):5.
50. Pal S, Bhattacharya M, Islam MA, Chakraborty C. ChatGPT or LLM in next-generation drug discovery and development: Pharmaceutical and biotechnology companies can make use of the artificial intelligence-based device for a faster way of drug discovery and development. Int J Surg. 2023;109(12):4382-4384.
51. Holzinger A, Keiblinger K, Holub P, Zatloukal K, Müller H. AI for life: Trends in artificial intelligence for biotechnology. N Biotechnol. 2023;(74):16-24.
52. Khan RA, Jawaid M, Khan AR, Sajjad M. ChatGPT - Reshaping medical education and clinical management. Pak J Med Sci. 2023;39(2):605-607.
53. Stokel-Walker C. ChatGPT listed as author on research papers: many scientists disapprove. Nature. 2023;613:620-621.
54. Lund B, Wang S. Chatting about ChatGPT: How may AI and GPT impact academia and libraries? Library Hi Tech News. 2023;40(3):26-29.
55. De Angelis L, Baglivo F, Arzilli G, Privitera GP, Ferragina P, Tozzi AE, et al. ChatGPT and the rise of large language models: The new AI-driven infodemic threat in public health. Front Public Health. 2023;(11):1166120.
56. Benoit JRA. ChatGPT for Clinical Vignette Generation, Revision, and Evaluation. medRxiv. 2023. doi: https://doi.org/10.1101/2023.02.04.23285478
57. Wang S, Scells H, Koopman B, Zuccon G. Can ChatGPT Write a Good Boolean Query for Systematic Review Literature Search? Computer Sci. 2023;1(1): arXiv:2302.03495.
58. Zielinski C, Winker M, Aggarwal R, Ferris L, Heinemann M, Lapeña JF, et al. Chatbots, ChatGPT, and Scholarly Manuscripts: WAME Recommendations on ChatGPT and Chatbots in relation to scholarly publications. Natl Med J India. 2023;36(1):1-4.
59. Sallam M, Salim NA, Barakat M, Al-Mahzoum K, Al-Tammemi AB, Malaeb D, et al. Assessing Health Students' Attitudes and Usage of ChatGPT in Jordan: Validation Study. JMIR Med Educ. 2023;9: e48254.
60. Ahn C. Exploring ChatGPT for information of cardiopulmonary resuscitation. Resuscitation. 2023;185:109729.
61. van Dis EAM, Bollen J, Zuidema W, van Rooij R, Bockting CL. ChatGPT: Five priorities for research. Nature. 2023;614(7947):224-226.
62. Stokel-Walker C. ChatGPT listed as author on research papers: Many scientists disapprove. Nature. 2023;613 (7945):620-621.
63. Sejnowski TJ. Large Language Models and the Reverse Turing Test. Neural Comput. 2023;35(3):309-342.
64. Hadi M, Al Tashi Q, Qureshi R, Shah A, Muneer A, Irfan M, et al. Large Language Models: A Comprehensive Survey of its Applications, Challenges, Limitations, and Future Prospects. TechRxiv. 2023:1-44.
65. Alternativas a ChatGPT: 5 opciones a tener muy en cuenta. 2023. https://www.neo2.com/alternativas-a-chatgpt/
66. Zabala T. La ética en la Inteligencia Artificial. Rev de Gestión de la Seguridad y la Salud en el Trabajo. 2023;5(2):78-82.
67. Linares G. Principios éticos para el desarrollo de la inteligencia artificial y su aplicación en los sistemas de salud. Editorial Politécnico Grancolombiano. 2022;11(2);137-161.
68. Tarik J. WHO issues first global report on Artificial Intelligence (AI) in health and six guiding principles for its design and use. Growing use of AI for health presents governments, providers, and communities with opportunities and challenges 2011. https://www.who.int/news/item/28-06-2021-who-issues-first-global-report-on-ai-in-health-and-six-guiding-principles-for-its-design-and-use
69. Castillo E. La UCAB anunció lineamientos para incorporar la inteligencia artificial en todos sus procesos. El Ucabista. 2023. https://elucabista.com/2023/06/20/la-ucab-anuncio-lineamientos-para-incorporar-la-inteligencia-artificial-en-todos-sus-procesos/
70. López-Loyo E. La inteligencia artificial: de lo real a lo probable. Gac Méd Caracas. 2023;131(1):14.
71. Parga RA. La inteligencia artificial en el sistema educativo venezolano: oportunidades y amenazas. Revista Eduweb. 2003;17(4):9-15.