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Applications of Artificial Intelligence (AI) in Medical Education: A Scoping Review

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Abstract. Artificial Intelligence (AI) is increasingly used to support medical students' learning journeys, providing personalized experiences and improved outcomes. We conducted a scoping review to explore the current application and classifications of AI in medical education. Following the PRISMA-P guidelines, we searched four databases, ultimately including 22 studies. Our analysis identified four AI methods used in various medical education domains, with the majority of applications found in training labs. The use of AI in medical education has the potential to improve patient outcomes by equipping healthcare professionals with better skills and knowledge. Post-implementation refers to the outcomes of AI-based training, which showed improved practical skills among medical students. This scoping review highlights the need for further research to explore the effectiveness of AI applications in different aspects of medical education.

Keywords. Artificial Intelligence, Machine Learning, Medical Education.

1. Introduction

The healthcare industry, in particular medical education, is being transformed by artificial intelligence (AI). AI has the potential to transform medical education by delivering personalized and adaptive learning experiences, increasing diagnosis accuracy, and facilitating data-driven decision-making [1]. Medical education has typically been one-size-fits-all, with students required to memorize large volumes of knowledge. However, AI can assist in tailoring the learning experience to the needs of the particular student, allowing them to focus on areas where they require more practice [2]. AI can also assist instructors in creating individualized learning programs, tracking learner progress, and providing real-time feedback [3]. While many published reviews report the specific type of AI and its effectiveness in the medical education process, however; this review aims to provide an overview of AI in the medical education domain, focusing on the type of Al methods used, classification, and area of implementation.

2. Methodology

This scoping review was conducted following the guidelines from the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA-ScR) [4]. We

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searched four databases: (PubMed, Google Scholar, Scopus, and ScienceDirect). The search strategy, which included population (i.e., medical students) and target intervention (i.e., artificial intelligence), was applied to the most used database listed earlier (Appendix A[2]). To minimize bias errors, the study selection and data extraction processes were carried out independently by the reviewers, thus increasing the validity and reliability of the work. The study selection process consisted of three steps: removing the duplicates in the 1485 retrieved studies, screening titles and abstracts, and reading the full text of the remaining studies. We then extracted data into an Excel sheet, which was synthesized using a narrative approach. Then, all included papers were summarized into simplified text and tables (Appendix B[2]).

3. Results

A total of 22 studies were included out of 1485 retrieved studies. Amongst these, 1220 duplicate studies were excluded. Through title and abstract reading, 47 studies were excluded, and 25 studies were excluded following the exclusion and inclusion criteria of being non-English studies, non-peer-reviewed articles, or scoping review text. Through full-text screening of the remaining studies, we end up with 22 studies that meet the scoping illegibility criteria. We also summarize the key characteristics of the selected studies (Details in Appendix C[2]). The demographics and other specific details can be found in (Details in Appendix D[2]). The results reveal that three AI branches were identified across different domains in the medical education field. Machine learning algorithms and virtual reality were the most commonly used ML and Dl methods (n=11), followed by Virtual Reality (n=9) and robotic skills training (n=2). These AI methods were applied across various medical education domains, with the majority found in training labs (n=10), followed by the surgery domain (n=7), orthopedics (n=2), ophthalmology (n=1), surgery/medicine (n=1), and behavioral health (n=1). The selected studies discussed the different AI technologies, evaluation metrics (Details in Appendix E[2]), and areas of implementation, as summarized in Table 1.

Table 1. Type of AI technologies used in the medical education domain.

Area of Implementation	Machine Learning/Deep Learning	Robotic skills Training	Virtual Reality	Grand Total
Behavioural Health			1	**1**
Ophthalmology	1			**1**
Orthopaedics	1		1	**2**
Surgery	3	2	2	**7**
Surgery/Medicine			1	**1**
Training Lab	6		4	**10**
Grand Total	**11**	**2**	**9**	**22**

[2] https://doi.org/10.5281/zenodo.7866503

The results demonstrate the application of AI techniques in various domains of medical education. In each domain, AI methods such as Machine Learning/Deep Learning, Robotics Training, and Virtual Reality have been implemented to enhance the learning experience and improve outcomes. In the domain of Behavioral Health, Virtual Reality has been used as a tool to create immersive and interactive environments, allowing students to practice their skills in simulated scenarios that mimic real-world situations. This approach helps learners better understand patients' psychological and emotional needs and fosters empathy and effective communication skills. In Ophthalmology, Machine Learning/Deep Learning has been applied to assist students in recognizing and diagnosing various eye diseases and conditions using medical images. The technology enables students to identify patterns and learn from large datasets, thereby improving their diagnostic accuracy and decision-making abilities. In Orthopedics, both Machine Learning/Deep Learning and Robotics Training have been employed. Machine Learning/Deep Learning aids in predicting patient outcomes, optimizing treatment plans, and identifying potential complications.

Robotics Training, on the other hand, provides hands-on experience for students to develop their surgical skills and precision, resulting in better patient outcomes. Surgery is a domain where all three AI techniques have been utilized. Machine Learning/Deep Learning assists in preoperative planning, diagnosis, and predicting patient outcomes. Robotics Training is used for developing surgical skills, including robotic-assisted surgeries, improving precision and minimizing surgical errors. Virtual Reality creates immersive surgical simulations that allow students to practice and refine their techniques in a safe environment. In the Surgery/Medicine domain, Virtual Reality has been employed to create realistic simulations of various surgical and medical procedures, enabling students to gain experience and improve their clinical decision-making skills without the risks associated with real-life procedures. In Training Labs, Machine Learning/Deep Learning and Virtual Reality have been widely used. Machine Learning/Deep Learning allows for personalized learning experiences by analyzing student performance data and identifying areas for improvement. Virtual Reality offers immersive training simulations, enabling students to practice their skills in a controlled and risk-free environment.

4. Discussion

The scoping review aims to emphasize the current applications and branches of AI in the medical education process. Among the 22 included studies, approximately 10 studies implemented various AI methods within training labs for medical students. The evaluation metrics were promising, as evident by the positive feedback from trainees. The post-implementation results demonstrated that AI-based training supported the enhancement of practical skills for medical students, employing a modern approach using artificial intelligence-based assistance. Additionally, the review highlights the diverse range of medical domains in which AI is being applied, including training labs, surgery, orthopedics, ophthalmology, surgery/medicine, and behavioral health. This indicates the adaptability of AI technologies, which can be tailored to specific fields and educational requirements.

Incorporating AI in medical education has the potential to revolutionize traditional teaching methods by offering personalized, adaptive learning experiences. AI-driven tools can identify students' strengths and weaknesses, enabling the development of

customized learning plans that target specific areas for improvement. This targeted approach can enhance knowledge retention and skill development, resulting in better-prepared healthcare professionals. Another notable aspect of AI integration in medical education is its capacity to provide real-time feedback and assessment. This allows students to track their progress, identify areas of weakness, and receive immediate guidance for improvement. Instructors can also benefit from AI-generated analytics, which can help them identify trends and patterns in student performance, adjust teaching strategies accordingly, and optimize the learning process. Despite the promising results and potential of AI in medical education, there are still areas that require further exploration and research. These include investigating the long-term effects of AI-assisted learning on student performance, evaluating the impact of AI-driven tools on instructor-student interactions, and exploring the ethical considerations of incorporating AI technologies in medical education.

5. Conclusion and Future Direction

With the increasing adoption of AI in the healthcare industry, it is crucial to incorporate this technology into medical education to ensure that healthcare professionals acquire the necessary skills for providing high-quality care in the future. This review offers valuable insights into recent AI applications in medical education and demonstrates their potential to improve learning outcomes, enhance students' confidence, and develop superior surgical skills. Consequently, we strongly emphasize the need for conducting further research to explore the effectiveness of AI applications in medical education. This exploration could potentially transform the entire educational system for medical students, given that AI is a rapidly growing field with numerous new advancements on the horizon.

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