https://www.mediresonline.org/

ISSN: 2836-6387

Open Access

Journal of Virology and Vaccination

Review Article

Investigating the perspectives, awareness, and preparedness of Medical Undergraduate Students concerning the usage of digital and AI elements in health systems: A review of research

Dimitrios Karaferis[1]*, Dimitra Balaska[2], Dimitrios Niakas[1]

[1]Department of Health Economics, Medical School, National and Kapodistrian University of Athens, 11527 Athens, Greece
[2]Department of Business Administration, University of West Attica, 12241 Athens, Greece

***Corresponding Author:** Dimitrios Karaferis, Department of Health Economics, Medical School, National and Kapodistrian University of Athens, 11527 Athens, Greece.

Received Date: 10 April 2026; **Accepted Date:** 28 April 2026; **Published Date:** 05 May 2026

Abstract

Background: The continuous assimilation of modern technologies in medical sector has imposed a corresponding evolution in education, with innovations like Digitalization and Artificial Intelligence (AI) gaining increasing importance globally. Nevertheless, the absence of AI and digital content in the formal curriculum reflects a broader challenge in adapting medical education to the rapidly evolving field of healthcare technology. The next generations of medical students must be more likely to incorporate digital and AI-based elements into their practice; therefore, this research seeks to examine medical students' existing perceptions regarding their role in medical education and practice.

Methods: This review explored how digitalization and AI-based innovations affect medical students' education. Researchers searched Scopus, Medline/PubMed, Embase, EconLit, Web of Science, and Google Scholar for articles published between January 2020-March 2026, using specific inclusions and exclusions.

Results: Many students demonstrate a strong interest in incorporating digital tools and AI-driven innovations into their learning processes. This has been supported by their belief in the necessity of these technologies for future medical practitioners. However, while students express considerable enthusiasm, they report sizeable gaps in both overall understanding of the technologies involved as well as in their experience using them. The internet and social media identified by the majority of students as the main source of information regarding AI and digital application technologies. Students' demographic characteristics, affect how understand, perceive, and engage with AI and digitalization.

Conclusion: The findings underscore the critical need to embed fundamental knowledge concerning digitalization and AI-driven advancements into medical curricula, aiming to empower practical skills of future medical providers. This integration must adhere to ethical principles and supported by institutional policies alongside curriculum modifications. Participation in experiential learning opportunities, like workshops, case studies, and team-based projects, can improve their ability to apply AI concepts in clinical environments, ultimately fostering greater confidence in handling developing technologies.

Keywords: Medical students; Artificial intelligence; Digitization; Medical education; curricula; Student readiness; knowledge; Perceptions; Teaching/learning strategies

Introduction

The field of medical knowledge is experiencing rapid growth, which compels physicians remain up-to-date and proficient in analysis, communication, and the rapid retrieval of medical information from diverse data sources. The COVID-19 pandemic has underscored the fact that digitalization and AI-driven tools are transforming the functions of physicians and greatly affecting medical teaching and learning through the establishment of metacognitive rich student-centered environments, requiring adaptation to these distinctly different healthcare settings compared to traditional teaching methods. Historically, medical education has depended largely on didactic methods, mainly through lectures and textbooks, which promote a passive learning attitude. Practical training methods have traditionally included cadaver dissections, clinical rotations under supervision, and direct interaction with patients for clinical skill development. Nonetheless, despite the effectiveness of the traditional teaching methods, there are certain challenges that come with them. These challenges include significant inconsistency of instruction, persistent challenges of coordinating standards across institutions, the potential for cognitive overload, and little room for customized learning for a given individual. Against this backdrop, integration of digital technologies and advances in AI marks a notable shift in medical education landscape. This evolution, marked by the emergence of advanced personalized learning models and immersive simulation technologies, is radically reshaping clinical education, presenting significant possibilities for improving curriculum design and fostering continuous professional development. With roots in constructivist and experiential learning theories, these tools give immediate feedback and assessment, fostering greater learner engagement. At the same time, they support medical students in reinforcing knowledge retention by encouraging active participation, reflective practice, and applying knowledge in real-world situations. Therefore, the readiness of future medical providers to harness and adopt AI and digital tools, along with the relevant knowledge and skills as a natural method of service delivery, is crucial for improving the quality of healthcare services offered. This implies that, among various other factors, institutions like universities must gradually guarantee that all stakeholders, including undergraduate medical students, obtain the necessary knowledge, skills, and attributes to utilize effectively these advanced technologies, by modifying their curricula accordingly [1-4].

Medical education to date has typically concentrated on cultivating communication skills pertinent to patient care and the implementation of systems-based practices following an initial phase of preclinical lectures. Nevertheless, recent research highlights the effectiveness of AI algorithms across multiple medical fields, such as ophthalmology, pathology, dermatology, radiology, and pulmonology. Despite the lack of evidence endorsing the integration of AI tools and digitalization into everyday patient care practices, and notwithstanding the possibility of a swift proliferation of various applications, opportunities for students to engage with universities and medical programs that impart these concepts are infrequent. Research examining students' perceptions toward these technologies related to specific fields is only now emerging. In some studies, it seems that most students want to integrate digital tools and intelligent algorithms, along with their application in clinical settings and their incorporation into educational programs. On the other hand, a few students express a desire to avoid certain medical specialties, like radiology, due to the belief that AI may pose a threat to the roles of medical providers. In the majority of them, medical curricula have not yet systematically integrated education in relation to AI and digitalization. However, given the growing involvement of AI-powered tools and digital technologies in clinical diagnosis, decision-making, and patient care, it is more than just desirable for medical students to develop basic skills that will help them navigate changes in the healthcare sector effectively [5-9].

Ultimately, the present study seeks to address a notable deficiency in undergraduate medical students' understanding, attitudes and satisfaction towards digitalization and AI-driven tools, their applications in medical practice, and their views on the need to integrate these elements into their medical curriculum. The development of evidence-based medicine has led to the expectation that physicians should have the maximum information, but also the appropriate skills and knowledge to utilize research and scientific methodologies to enhance medical practice. Integrating AI and digital technologies into medical curricula can equip students with a robust understanding of AI and digital principles, applications, and the associated ethical considerations. The impact of personal experience with AI and digitalization is correlated positively to performance and this is recognized worldwide. Consequently, inadequate preparedness among graduate students can negatively affect the quality of healthcare and its outcomes.

Materials and Methods

Aim of the Study

The main aim of this review was to explore the worldwide opinions (including perceptions, beliefs, attitudes, and preferences) of undergraduate medical students toward AI-based and other sophisticated digital technologies. The survey gathered data on students' familiarity and understanding of digital applications and AI-powered innovations, and how these can contribute to enhancing their skills, elevating their readiness and confidence in utilizing these technologies and ultimately better preparing future physicians with the neces-

sary expertise. In addition, we aimed to determine whether variables such as gender, age, or other demographic factors influence their opinions. Under the mentioned assumptions, this study explores the following primary Research Questions (RQs) that constitute its central focus:

RQ1. In what ways does the introduction of digital and AI-driven technologies into healthcare change the need for student education in medical schools?

RQ2. What advantages do modern technologies offer in enhancing the medical knowledge and practices necessary for students to be properly prepared in an ever-changing environment?

RQ3. What degree should medical schools and faculty consider including AI/digitalization in their medical curricula and what could be done to improve infrastructure or training?

RQ4. What are the essential elements and concerns that medical schools should consider regarding modern technologies in their curricula?

Methods

This review aimed to examine relevant factors such as awareness, interest, perceived advantages, concerns, attitudes, and training requirements related to advancements in digital technologies and AI innovations targeting the elderly. Additionally, it sought to assess how these developments influence the education and clinical practice of medical students. For this reason, a targeted literature review was carried out across multiple academic databases, such as Scopus, Medline/PubMed, Embase, EconLit, Web of Science, and Google Scholar. Additionally, this review examined how these developments are shaping medical schools' curricula. Moreover, emphasis was placed on the innovative usage of digital and AI-based applications among undergraduate medical students, alongside the increasing moral and ethical discussions surrounding the usage of these technologies as instruments for preparing future medical professionals. The research was limited and included electronic databases spanning from January 2020 to March 2026. The search terminology indexed vocabulary and free-text keywords related to AI, digitalization, and healthcare, was used through the following Boolean operators and Medical Subject Headings (MeSH): ("Artificial Intelligence"[Mesh] OR "AI" OR "Digitalization" OR "Machine Learning") AND ("Perception" OR "Attitudes" OR "Opinions" OR "Views") AND ("Teachers"[Mesh] OR "Faculty" OR "Educators" OR "Instructor" OR "Tutor" OR "Professor" OR "Lecturer" OR "Teacher") AND ("Education"[Mesh] OR "Medical Education" OR "Health Professions Education" OR "Health Sciences Education" OR "Medical Practice" OR "Clinical Practice" OR "Training") AND ("Health Professions" OR "Health Careers").

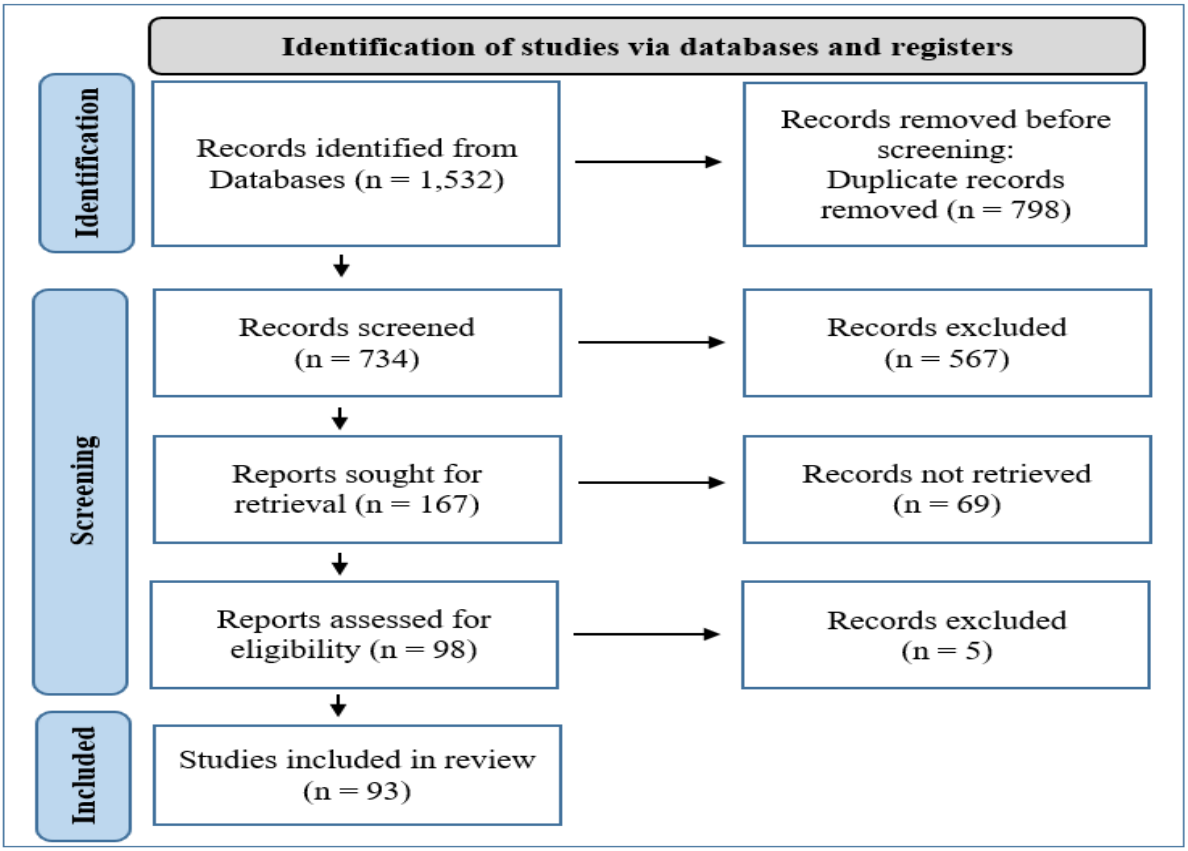

Figure 1. PRISMA-style flow diagram depicting study identification, screening, eligibility, and inclusion process.

This literature review was conducted in accordance with the reporting standards described by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. In this context, the researchers involved five main steps where the researchers: 1) identified relevant studies, 2) screened these studies, 3) extracted and collated the data, 4) synthesized the gathered information, and 5) presented the results, as illustrated in Figure 1. A total of 1,532 studies were initially identified. The research team's information specialist exported these records to Zotero and removed duplicates, yielding a total of 734 unique articles. An additional pilot test was then conducted before the titles, abstracts and keywords were rated independently by two researchers against support for study objectives with a focus on English-language studies that could provide widely applicable insights. Using this approach, 167 articles were identified after screening following the exclusion of 567 articles. The same reviewers subsequently performed a more in-depth review of the full texts to determine whether they met our eligibility criteria with respect to the study aims. At this stage, 98 eligible articles were selected for in-depth evaluation and at least five more were excluded after full text assessment. In total, 93 articles were included in the qualitative synthesis [10].

Results

The research articles considered in this study, are drawn from different regions like North America, Asia, Europe, the Middle East, and Australia; they indicate the growing trend of evaluating the way undergraduate medical students understand the effects of digitalization and AI-driven innovations on their education and future career development. Analyzing students' perspectives is crucial for ensuring that the application of modern technologies align with the objectives of medical academic performance, while also directing the development of programmes that enhance educational outcomes, and adequately meet student needs. Although research-focused studies thus far have yielded significant insights regarding the various applications of digitalization and AI integration, it is crucial to also take into account the human element.

Perspectives on innovative Technologies in medical curricula

Beyond its role as a technical tool, AI also possesses far-reaching implications that are significant, since some aspects affect the physician-patient interaction. Understandably, the role of undergraduate medical students and their training is recognized as essential and particularly for the upcoming exploitation and enhancement of digitalization and AI-embedded platforms, in meeting the continuously changing requirements of modern medical practice outcomes. Already, universities located in wealthy countries have begun to integrate AI-supported applications, simulations and digital courses into their medical curricula, mostly on an optional rather than a mandatory basis. However, medical schools in less affluent regions often struggle with a lack of essential infrastructure.

Optimism vs. Skepticism

Undergraduates' perspectives regarding digitalization and AI-enhanced tools in the context of educational and practical experiences highlighted several positive trends. In general, students view AI positively, with over 75% expressing the belief that the integration of these modern technologies would have a positive effect on the education of future medical practitioners, their employability and would benefit their careers, through the usage of virtual reality (VR), simulations and personalized learning. It is different from traditional learning tools like textbooks and lectures, which frequently promote passive knowledge acquisition. Along the same lines, numerous qualitative studies have showed that more than 80% of undergraduates demonstrated a favorable attitude towards AI and digitalization, holding the belief that these emerging innovations not only encourages active learning, but will also be decisive for improving the development of clinical practice, diagnostic accuracy and decision-making. In recent reports, students describe AI as a collaborator rather than a rival. On the contrary, there is a skepticism towards the adequacy of existing infrastructure to support the incorporation of AI and digital resources into the curriculum of the field of medicine, especially in developing countries. This skepticism includes critical limitations and considerations pertaining to infrastructural barriers, faculty and institutional readiness, ethics and data privacy, alongside a widespread lack of trust in AI's technologies. Several studies anticipated reduced patient-provider interaction and worries about the possible dehumanization of medical care. Likewise, prominent issues remain towards the possible replacement of specific medical specialties by digital and AI-powered applications in the near future. Likewise, additional research raises concerns that AI may limit the expression of "clinical judgment" and "practical skills" by undergraduate students. In conclusion, it becomes clear that the existing literature provides a variety of different evidence according students' understanding of digital and AI-driven innovations in relation to their academic background [11-20].

Benefits Recognized

Undergraduate medical students recognize the high potential of digital technologies based on Artificial Intelligence to enhance access to medical information and practices, especially their ability to aggregate, filter and summarize extensive observational data, formulate diagnoses and ultimately contribute with greater confidence to decisions. Similarly, they consider that the use of simulated patients and intelligent mannequins can reproduce complex human pathophysiology by reacting adaptively to clinical interventions,

thus contributing to the familiarization of students in difficult emergency situations. Furthermore, all students involved expressed their gratitude for the timesaving benefits provided by AI. All these capabilities are critical for advancing medical research, improving decision-making processes, optimizing medical advice, and increasing the accuracy and efficiency of diagnostic methods in clinical settings. They also help with imaging analysis, laboratory diagnosis, documentation, workflow optimization, and speeding up various administrative tasks. Notably, students appear to recognize the ability of AI-based digital technologies role to improve patient care, through improved clinical reasoning which is shaping personalized treatment and enhancing efficiency across various medical procedures, including patient scheduling, preventive health strategies, diagnostic accuracy, record management, and the expedited treatment of rare diseases and genetic disorders. Moreover, the benefits identified also include the simplification of medical consultations, especially in rural regions, through remote and 24/7 operation, and reducing human errors [7,11,21-23].

A review by Dave and Patel (2023) concluded that AI-driven digital modalities notably enhance and facilitate human efforts than traditional methods, by fostering distance learning, training, and educational advancement for both students and educators in locations with a paucity of human capital resources, affecting both the academic and healthcare sector. In this sense, large language models (LLMs) like ChatGPT have proven to play a prominent role in the field of medical education serving as virtual patients and medical instructors, developing case studies, or even designing personalized learning programs. Similarly, undergraduates who utilized ChatGPT demonstrated superior performance in terms of user experience, functionality, and content organization compared to those who chose to rely on traditional search engines for their needs. Numerous research studies have brought out the importance of AI-assisted learning through VR and chatbots, providing students with accurate information and the opportunity to repeatedly practice particularly in complex medical procedures that they find themselves lagging behind. It is an approach that classifies operator skills with a high degree of sensitivity, helps students strengthen their clinical reasoning abilities, enhances their engagement and motivation for learning through real-time feedback, and automatically detects errors, while minimizing the potential risk of harm to actual patients [24-27].

Emerging Challenges, Concerns and Fears

Despite its benefits, just like any other technology, the use of innovations based on digitalization and AI in the context of student learning poses certain ethical and social concerns, as well as skepticism regarding the methods of collecting, storing and utilizing data. AI-augmented tools vary in their capacity to adjust to natural language, customize content, and assimilate user feedback. Thus, they serve as complementary options rather than conclusive answers. Research has indicated worries that dependence on AI could diminish critical thinking capabilities, and ongoing reliance on AI-driven tools could lead to a decline in fundamental skills, critical thinking, and problem-solving abilities. Students voiced apprehensions about confidentiality, privacy, and the opaque nature of numerous AI systems. Specifically, expressed doubts regarding the techniques employed for data collection, storage, and usage. A third of medical students report being content with the existing standard of data protection training. Of these, only a small percentage (~20%) of medical students recommend data protection training, considering that application developers and medical institutions are responsible for ensuring high data protection. Concerns regarding the lack of transparency and data governance also included broader issues related to accountability and responsibility for decisions made by AI integration. This situation complicates students' understanding of the reasoning behind specific answers and to identify methods for correcting their errors, with participants questioning about what will happen and what responsibilities will be assigned to them when errors are made while utilizing AI as a reference. It appears that the assessment of the effectiveness of AI-driven digital applications and their accuracy in making critical decisions presents significant communication challenges, which stem to a large extent from the knowledge gap that exists between medical professionals and engineers who design AI systems [18,19,21,27-37].

Various ethical and regulatory considerations are rated by medical students as of utmost importance. The inability of AI-based applications to perpetuate biases in algorithms, the lack of transparency, and its failure to replace fine-grained human judgment. As such, the need to develop bias detection mechanisms to identify and correct inequalities in decision-making regarding AI, while regular assessments by various health professionals are considered to be able to contribute to improving clinical judgment and decision-making processes. Striking this equilibrium holds particular importance, especially within data-intensive disciplines such as radiology. An excessive dependence on artificial intelligence in these contexts could potentially lead to several adverse outcomes, including a decline in cognitive abilities among future physicians, a reduction in authentic learning experiences, instances of academic misconduct, and an impaired process of knowledge acquisition. Another important aspect pertains to the protection and security of private information and sensitive data, since any application of AI involves huge amounts of data that could inadvertently have confidential information related to students or patients. In light of this, the usage of AI for educational purposes must be done while adhering to strict legislative criteria, such as those provided by the General Data Protection Regulation (GDPR) or the Health Insurance Portability and Accountability Act (HIPAA).

Equally, the appropriate usage of AI by students poses another set of issues. Of particular concern is the risk that students possibly submitting artificially generated papers as their own, which could compromise not only the integrity of the education process but also the development of critical thinking skills in students. The solution to such issues involves the development of ethical guidelines by academic institutions, the introduction of strict policies, and the formation of an environment where the ethical utilization of technological resources will be encouraged. Furthermore, it should be noted that recent studies have shown that less than 20% of AI training courses offered within the UK incorporate any sort of data protection assessment. When it comes to interactions with patients, the majority of students (ranging from 40% to 50%) are concerned about the possibility of AI eroding essential elements such as empathy and respect required for establishing effective communication between doctors and their patients. As for the existing literature on the matter, most studies emphasize the concern that the use of AI in diagnosing diseases and prescribing medications may contribute to dehumanizing the process of treating patients [5,18,19,21,29,30,34,38-46].

Specialty Impact

The awareness of the effects of AI-driven digital technologies varies widely among medical specialties. It is often argued that robots will not replace providers, as the core of medicine lies in the physicians-patients close relationship. Nevertheless, a significant number of students are considering the potential for AI to emerge as a formidable competitor, particularly in fields such as pathology, ophthalmology, radiology, and dermatology, as well as other fields where AI has demonstrated superior performance compared to the most skilled professionals. In this regard, many students predicted that AI will become an integral part of their professional in the next 10 to 20 years; particularly, those specialties that involve repetitive and predictable tasks are the most vulnerable to automation. Specifically, in a study conducted in Australia, students identified radiology (~73%), pathology (~58%), and medical administration (~45%) as specialties most likely to be affected by AI, while psychiatric counselling (~60%), palliative care (~50%), and obstetrics and gynecology (~40%) were recognized as the fields least likely to be impacted by AI. It is normal for students to exhibit anxiety and apprehension regarding the potential of AI to supplant clinicians or displace their employment; such sentiments may even shape students' career decisions. About one-third of students indicated that the progression of AI in healthcare will affect their future specialty selection. These results underscore the necessity for strategies aimed at addressing the current workforce's concerns, as well as the importance of retraining and redefining roles to enable healthcare professionals to adjust to AI-enhanced workflows [21,29,30,34,36,47-49].

Awareness of Technological Advancements

Moderate but Superficial Knowledge

While aware of the existence of Digitalization, robotics, telemedicine, and a wide array of AI tools and techniques like machine learning (ML), deep learning (DL), natural language processing (NLP), many students have a limited understanding of their practical, technical, or ethical applications. Most findings indicate that that students possess a fundamental comprehension of digital and AI components; however, they need a more profound grasp of their application in the medical field, as they do not have sufficient knowledge and skills to engage with these innovations. In particular, research has shown that 30% of students and 50% of educators were acquainted with AI-powered tools, while around 40% of educators and 20% of students did not have a basic understanding of AI, with over 60% indicating that they had not undergone formal training in this area. The vast majority of undergraduates believe that integrating AI and digitalization into medical education is essential. In addition, many emphasized the necessity of comprehensive educational and training programs for medical providers, ensuring that they are well-prepared for an AI-integrated future and enchase their ability to develop solutions that seamlessly fit into with existing systems. Undergraduates expressed a strong interest in acquiring knowledge about AI and digital components, with the aim to remain informed about the latest developments in cutting-edge technologies. This interest stems from their belief that physicians who are familiar with these advanced technologies may outpace those who do not utilize them in this highly competitive environment. Research shows that a lack of exposure to AI can lead undergraduate medical students to feel anxious, feel inferior to their peers who have received AI-related training, and further influence their future career paths [42,50-52].

Sources of Knowledge

A high percentage of medical undergraduates reported that their main sources for learning opportunities about AI and digitalization were informal and not included in their medical curricula. They learned through extracurricular activities (e.g., talks, webinars, lectures, presentations), participating in international conferences, reading published articles, having discussions with colleagues, while the most common activity was interacting with social media. Nevertheless, these sources generally provide a clear overview of a topic, but often do not provide sufficient detail to fully understand the key concepts. Despite undergraduates' awareness, only a small percentage, usually ranging from 11 to 25%, have participated in university courses or external workshops focused on training in robotics, AI or digital elements in medicine. This low participation in formal courses inevitably leads to a noticeable discrepancy between theoretical knowledge and practical application within the field of AI. This also demonstrating a concern about what individuals understand and what they

can actually apply in their professional activities. Similarly, the fact that many future providers are independently applying AI-driven tools on their own, without formal guidance, shows the immediate necessity of establishing measures to evaluate current usage and develop proper curriculums [9,11,15,36,55-57].

Knowledge Gaps and Learner Autonomy

A major obstacle to the integration of AI-driven digital technologies from a cognitive perspective is the prioritization placed by students on medical subjects, which is justified by their already overburdened curricula. In addition, studies reveal that students struggle to accurately define or differentiate AI terms such as ML, DL, LLM, and NN. In addition, more than two-thirds of medical students express a necessity for training in digital communication, data skills, data management, ethical principles and clinical reasoning. It seems that a lack of AI and digital literacy contributes significantly to this issue, as undergraduate students often demonstrate weaknesses in basic skills correlated to computer science, mathematics, and programming. This gap may be due to several factors, such as insufficient practical training or reliance on conventional educational methods that focus on theory rather than practical application. However, based on constructivist and experiential learning theories, AI-based digital tools like virtual simulations and adaptive learning platforms encourage active, student- centered learning, enabling undergraduates in acquiring knowledge through practical application and participation in real-world environments. These newly developed learning methodologies align with digital pedagogy frameworks that focus on flexible, personalized, and contextual learning experiences. Likewise, virtual and augmented reality technologies provide undergraduates with immersive experiences in interactive settings, consequently enhancing learner engagement and the effectiveness of education. The research demonstrates that the key strength of AI-driven technology lies in its ability to facilitate personalized learning experiences, which are critical for independent learning. Therefore, adopting innovative educational approaches may aid in closing the knowledge gaps that remain, through the use of preferred learning methods including workshops, collaborative tasks, scientific conferences, and extracurricular activities. These methods would be easier to integrate into a comprehensive medical curriculum and would likely be more enjoyable [14-16,34,54,55,58-61].

Medical Students Disciplines Differences

Approximately one-third of undergraduate medical students expressed neutrality or dissatisfaction with traditional teaching approaches. The majority of students emphasized that methods overemphasized theoretical knowledge, thereby overlooking the benefits of practical clinical experience. Regardless of their preferred career path, students who self-identified as "tech-savvy" showed significantly higher readiness and positive attitudes toward diagnostic accuracy, regardless of whether their curriculum included formal training in AI-based technologies. Existing literature shows that AI-driven applications in medical education improve the feedback process, which is crucial for the continuous learning of trainees and for maintaining the provision of quality care. In terms of the analysis of exam questions, students studying clinical medicine exhibited a markedly greater inclination towards the use of automation and AI compared to their counterparts in medical engineering. Clinical laboratory tests are also essential for providing necessary information required for the diagnosis, treatment, and monitoring of diseases. This aspect is fundamental to modern healthcare, which continually integrating new technologies to improve the precision of clinical judgments and ensure patient safety. In the realm of information retrieval, undergraduate students specializing in rehabilitation therapy exhibited a markedly lower demand for usage compared to their peers in basic and clinical medicine. The above findings accentuate that even though AI helps in understanding and preparing trainees for learning materials or prepared more effectively in clinical rotations, it is important to recognize that should not be considered a full replacement for human thinking and reasoning. Studies reveal that AI lacks the ability to incorporate extraneous or contextual information along with sensory and non-verbal signals, and critically, it tends to undermine some human qualities that are essential in medical practice [45,49,58,61-65].

Preparedness and Training in Medical Education

Lack of Formal Training

The rigorous nature of medical curricula leaves little opportunity for the integration of new topics without causing students to feel overwhelmed. It is widely recognized that medical students face increasingly demanding curricula and are more vulnerable to stress than their peers in other academic fields. Moreover, the absence of mandatory courses in medical schools, combined with the insufficient experience or untrained faculty members, hinder the rapid adoption of innovative educational approaches and teaching methodologies. Based on the above, it is justified that a significant number of undergraduate students report that they have not received formal training or have not participated in specific academic courses based to AI-driven digital health technologies during their studies. While many undergraduates stated that they have self-educated through informal means, such as online research or the use of social media platforms. Likewise, a consistent observation in this research was the strong student demand for direction from faculty about the effective utilization of AI for educational purposes. It is worth noting that nearly 75% of undergraduate students report that their medical training has not adequately equipped them to deal with AI and digital applications; consequently, they feel unprepared to tackle the challenges presented by these technologies in the healthcare ecosystem [5,6,14-16,21,31,57,66-70].

Demand for Curriculum Integration

Undergraduate students, regardless of their field of study, agreed that medical schools represent the most appropriate environment to obtain the appropriate knowledge about digital and AI-driven technologies relevant to healthcare. It is found that there is a significant demand from students for the incorporation of more structured opportunities in medical schools, particularly in those specialties that require improved practical skills and increased preparedness. In many quantitative and qualitative exploratory studies conducted, it is revealed that a significant percentage of students recommended the revision of the medical curriculum. Importantly, even those students who were against the development of AI in medical fields recognized the necessity of providing AI-focused training to undergraduate students. Moreover, students further supported the adoption of a balanced strategy that combines theoretical knowledge, practical implementation, and research o experiences. AI is seen as a transformative factor in medical education, particularly through the application of sophisticated visualization techniques, such as 3D models and animations, which act as engaging and effective educational tools. The findings also implies that AI-related subjects that captured the interest of students across all academic years included radiology and digital imaging, predictive models for diseases, as well as personalized health data and device monitoring. These topics were also perceived as the most significant challenges influencing the medical field. Nevertheless, students expressed their preference for engaging with AI as an elective course, rather than a mandatory one, with 65% preferring the former and 35% the latter [6,9,14-16,29,57,68,70-74].

Preparedness Level

Future medical service providers are required to have the ability to objectively evaluate the application of AI-powered systems, take into account the differences between algorithms designed for medical purposes, improve their understanding of data extractions from, and consequently become informed users. Undergraduate medical students generally demonstrated a moderate degree of preparedness and readiness (often scoring above 3 on a 5-point scale) regarding digital and AI elements, characterized by significant enthusiasm and recognition of the importance of AI in medicine. However, their expertise in cognitive areas (technical, ethical, and legal frameworks) tends to be less developed than their "visionary" ability to identify potential opportunities. Despite variations in preparedness, AI can serve as a personalized educational tool, as it has the potential to enhance learning by adapting content according to the user's skill level, assisting learners with challenging tasks, and acting as a continuous virtual instructor [34,67,75-78].

Barriers to Readiness

Primarily, a growing body of literature that argues that in relation to the integration of digitalization and AI-based tools into medical curricula, a comprehensive and universally applicable framework has yet to be established. Such a framework would ensure the formulation of targeted learning outcomes, sufficient practical exposure and standardized implementation guidelines, aligned with the modern demands of the healthcare system and society. Moreover, the majority of medical undergraduates believe that the delayed deployment of AI-powered systems into curricula was the lack of financial resources within educational institutions. Indeed, in many high-income countries, structured AI-based training is progressively being integrated into medical curricula; however, in developing countries, the presence of AI-based tools and digitalization in formal curricula remains significantly inadequate. Similarly, there is a lack of specialized guidance from teaching staff, which results in insufficient practical training and guidance. Actually, studies have recorded the views of faculty members, who, while recognizing the importance of AI-based applications in medical education and generally supporting its integration into the medical curriculum, state that they feel unprepared due to lack of familiarity, institutional constraints, and a scarcity of faculty with expertise in AI, and ethical dilemmas. All these challenges culminate in students being insufficiently equipped for healthcare systems that integrate digital and AI technologies [9,18,55,65,68,70,72,79-84].

The role of demographics in acceptance of AI and digital elements

There is no difference between genders in their readiness to embrace the incorporation of digitalization and AI-based components into their educational experiences. Nevertheless, numerous studies indicate that male students possess a greater understanding of AI compared to their female counterparts. Moreover, male students generally show a preference for topics related to high-tech medical technology within the curriculum, while women tend to favor topics related to personal interaction between patients and physicians, utilizing their senses during physical examinations. The difference in income was considered as a reflection of the students' opportunities for direct interaction with AI and digital technologies. In addition, students from different academic years showed varying degrees of interest in areas such as medical genetics and genomics, precision medicine, drug development, clinical trials, as well as diagnostics and clinical decision support. Academic year significantly influences medical student acceptance. Research have revealed that medical students in their first and second-years, who primarily study basic biomedical sciences, tend to perceive AI as a theoretical educational resource (e.g., adaptive quizzes) rather than a clinically relevant tool. In contrast, third-year students are more prepared than those in the fifth and sixth years, who may exhibit more reluctance as they are worried about being replaced in their jobs or scared of the complexi-

ties of clinical decision-making [83-88].

Geographic concentration of research concerning digitalization and AI-powered innovations in medical education

Research focusing on the digitization process and AI-based tools shows a significant geographic concentration of activity in North America, particularly those pertaining in the areas of medical education, simulation, and automated or assisted assessment methodologies. In this scientific area of interest, renowned universities in the U.S.A., are pioneering the charge in adopting quickly the digitalization and AI courses into their medical curriculum and overcoming the restrictions posed by the need for practical experience and digital competency in the process. Despite these courses are not yet mandatory, AI augments but does not replace traditional teaching methods, covering key topics like machine learning, data analysis, and the ethical considerations surrounding AI. Accounting for about half in terms of publications, the U.S.A. is the most productive globally, whereas Canada serves as a major hub for virtual simulations.

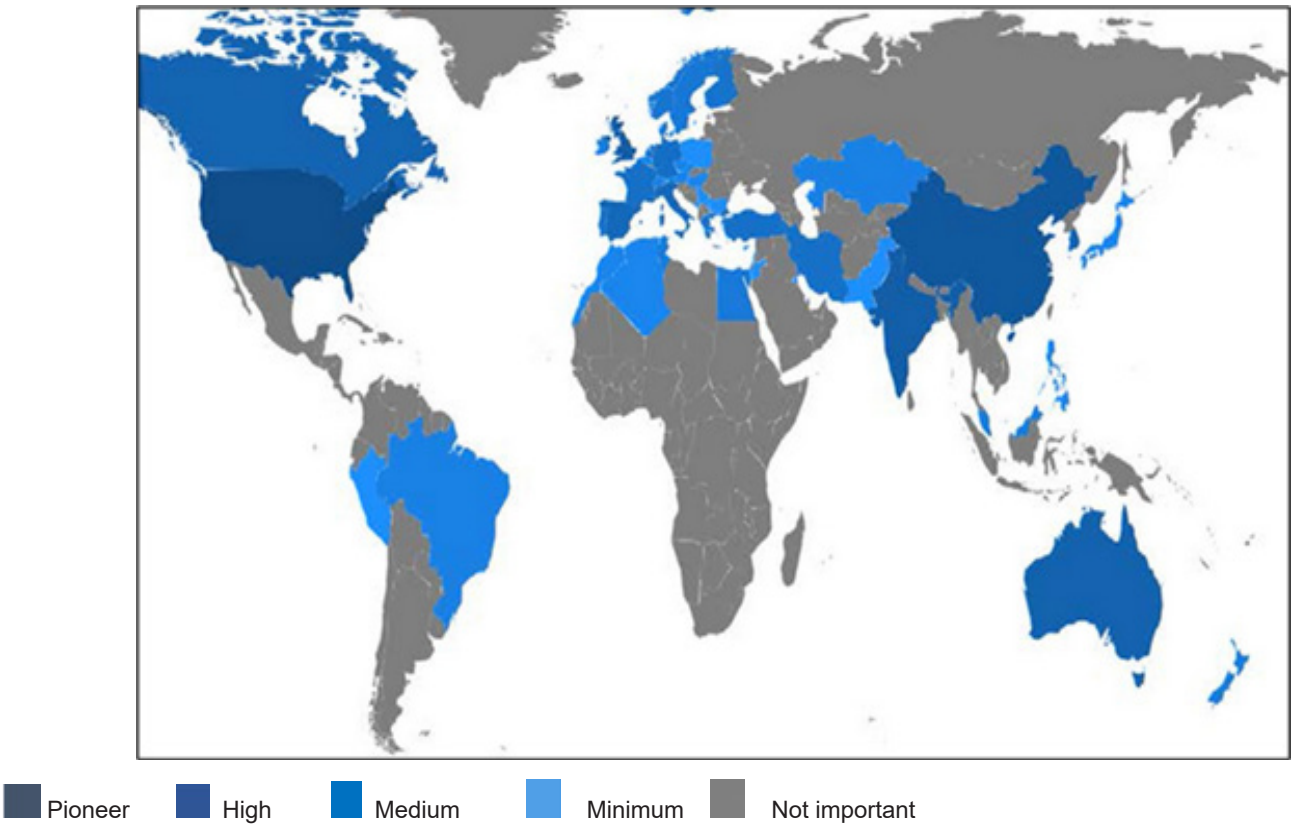

Figure 2. The magnitude of interest in medical education based on AI-powered innovations and Digitalization

In Asia, both China and India appear to be showing rising rates in the publication of digital and AI-related articles and patent applications. Singapore and South Korea are making notable efforts to develop simulation centers and having the highest impact on citations. Europe accounts approximately 18% of published research on medical education. Despite the overall positive sentiment among European medical students towards AI adoption and the fact that they recognize the lack of formal training, research shows that more emphasis should be placed on the privacy, quality, and ethical boundaries of the digitalization and integration of AI in educational environments. A study conducted in Germany, Spain, Belgium, and Holland, found that there is a generally positive outlook for AI in future medical practice, especially for administrative tasks and the analysis of health data. Similarly, there has been significant growth in Israel, the United Arab Emirates, and Saudi Arabia as these countries strategically allocate resources to digital health simulation and education initiatives. Studies done in Australia and the UK highlight the lack of readiness and low literacy levels among undergraduates. In essence, these global results point towards the major trend that future medical professionals will need to extensively engage with AI and digital technologies in their medical education. Besides that, global organizations like the World Health Organization (WHO), the World Medical Association and American Medical Informatics Association (AMIA), emphasize the necessary requirement for "data literacy", which will empower future physicians to work

alongside with AI-driven platforms while maintaining their clinical judgment. Collectively all these results are in support of the common global tendency for medical education to incorporate more comprehensive training on AI and digital technologies [5,15,16,18,54,82,89-92].

Discussion

Despite undergraduate medical students, globally have adopted a positive attitude regarding digital and AI developments and acknowledge the critical importance of these technologies to the future of medical practice, the current educational framework does not support this. The gap between the readiness of the healthcare medical workforce and the requirements of the emerging healthcare sector underscores the necessity of a more holistic approach to education and preparation of future providers to participate actively in the ever-changing healthcare environment. To meet this increasing demand for competencies in AI-based applications and digital elements, it is essential to reform medical school curricula. Given the growing acknowledgment of the importance of literacy in the rational application of digitalization and AI innovations in medical education, there is a concerted effort to modify curricula to harness their advantages while addressing their challenges. Some academics argue that while AI has the potential to significantly transform medical curricula, it should only serve as a supplementary resource to traditional undergraduate curricula. Others argue that courses on AI and digitalization should be mandatory and, in many cases, even considered in exams for certification of specialization to ensure that future medical providers will be "AI-ready". Furthermore, many researchers emphasize that interaction with actual patients facing authentic medical issues, and as such is essential as the most effective training for students. While the presence of bias in AI-enhanced educational environments raises significant concerns, it is expected that ongoing research will significantly mitigate this issue, promoting a more equitable learning environment. Faculty members ought to emphasize methodologies about AI-driven applications that grounded in evidence, hands-on training, industry involvement, continuous professional development, and collaboration across disciplines. Even more, educational institutions must establish structured collaborative learning experiences that merge health education with data science, while applying an ethical framework for AI analysis. The emphasis of these concepts should be on the core principles of AI, avoiding complex technical details. Medical schools are required to create the conditions for medical students to collaborate with AI professionals already working in the healthcare sector. For this reason, student engagement should be encouraged through hands-on workshops that emphasize the development of digital and AI-related skills [34,67,68,77,84,93-97].

To ensure that medical students cultivate an in-depth fundamental knowledge of digital health and AI practices, it is recommended to implement the following main axes of reform in the curricula, in the following manner:

- Longitudinal Curriculum Reform, digital and AI-driven technologies should be introduced in the preclinical years, focusing on fundamental principles, and should evolve in complexity as students advance through clinical education, rather than being treated as a separate module. Curricula must equip students to effectively utilize of AI-powered digital technologies, work collaboratively with AI systems, and analyze complex datasets within clinical settings. Early exposure helps with a more comprehensive understanding of AI-based applications, becoming more familiar, and being confident in recognizing the advantages and limitations.
- Practical Exposure, instead of relying on theoretical lectures, medical curricula should incorporate practical activities like workshops, simulated telehealth, and AI-enhanced case studies rather than depending on theoretical lectures. Furthermore, AI faculty members suited to the needs of each student can be used to study anatomy, surgical methods, diagnostic skills, and decision-making in a realistic but controlled and dynamic clinical environment, with VR and augmented reality (AR) building not only skills but also confidence and flexibility for future medical personnel to use AI-powered technologies to maintain quality patient care.
- Focus on Ethics and Humanism, AI ethics, data privacy issues, and the strong physician-patient relationship should matter more than just technological prowess. By analyzing various technological and ethical issues via case studies, students can develop critical thinking skills. Meanwhile, data analysis will enable undergraduate students to evaluate the accuracy and therapeutic value of AI-generated results.
- Interdisciplinary Collaboration, Collaborative workshops bring together medical, computer science, and engineering students, helping them grasp an algorithm's fundamental logic and its limitations. There is an urgent need to integrate medical statistics with clinical reasoning into the current curriculum to encourage data-driven decision-making as an alternative approach to diagnosis.

Limitations

The current research has some limitations. This study did not quantitatively assess how AI-based learning affects satisfaction, learning outcomes, or other measurable aspects of medical education. Doing so would have reinforced its qualitative findings. Moreover, as the study concentrated on understanding of medical students' perceptions, the perspectives of other stakeholders, including faculty members and healthcare providers, were not included, presenting an opportunity to be explored in future research.

Conclusion

Globally, there is an increasing use of AI-technologies and other digital solutions in patient care, recognizing their multiple benefits and increasing prevalence. Notwithstanding the escalating interest in these emerging technologies, medical school curricula has lagged behind the significant advancements in AI-based innovations and Digitalization. As a result, medical students are often forced to seek information independently and rely on social media and the internet to reinforce their knowledge. Numerous research studies have shown a high level of enthusiasm among undergraduate cohort, which has been encouraging of incorporating digital and AI-focused topics in medical curriculum. It is quite obvious that student involvement needs to be directed positively and strategically within the bounds of effective curriculum and assessment practices. This demand is accompanied by concerns about ethics, bias and governance, in the integration of AI-driven digital technologies into learning and assessment contexts. In addition, a significant concern expressed by undergraduates relates to the threat to employment opportunities that the healthcare sector will suffer due to digitalization and AI-innovations. Nevertheless, there is a growing consensus that AI-based technology should be viewed as an assistive tool to enhances independent learning, clinical reasoning, and reduces cognitive load, thereby allowing future medical professionals to focus more on patient-centered care. Simulations in virtual worlds supplement, rather than replace, direct patient encounters, because caring for patients in the real world necessitates empathy, communication, and adaptability-qualities that AI cannot fully imitate. However, without a well-structured curriculum and sufficient direction from faculty members, it is impossible to develop a strong knowledge basis in these areas, which may explain the inadequacies observed in undergraduate students.

Abbreviations

AI, Artificial Intelligence; AR, Augmented Reality; ML, Machine Learning; NLP, Natural Language Processing; LLMs, large language models; VR, Virtual reality;

Funding: None.

Declaration of conflict of interest: The authors declare that they have no conflict of interest.

Author contributions: DK led the research and supervised the methodological development. DB and DN were involved in the literature search and selection, analysis of included studies and interpretation of findings. All authors contributed to the original writing, critical revision and editing of the manuscript, ensuring accuracy and consistency of content. They also approved the final version of the article and take responsibility for its content.

Ethical approval: The ethical approval was not required, as the study conducted did not involve any ethical concerns or issues.

ORCID

Dimitris Karaferis https://orcid.org/0000-0002-7287-8686
Dimitra Balaska https://orcid.org/0009-0005-3288-7085
Dimitris Niakas https://orcid.org/0000-0003-0528-755X

References

1. Dimitris, K., B. Dimitra, and P. Yannis. "Digitalization and artificial intelligence as motivators for healthcare professionals." *Japan Journal of Research* 6, no. 3 (2025).
2. Fahim, Yosri A., Ibrahim W. Hasani, Samer Kabba, and Waleed Mahmoud Ragab. "Artificial intelligence in healthcare and medicine: clinical applications, therapeutic advances, and future perspectives." *European Journal of Medical Research* 30, no. 1 (2025): 848.
3. Karaferis, D., Balaska, D., Pollalis, Y. The Essential Importance of Virtual and Simulation Technologies in Modern Medical Education. *Biostat Biom Open Access J*. 2025; 12(2): 555832. https://doi.org/10.19080/BBOAJ.2025.12.555832
4. Karaferis, Dimitris, Dimitra Balaska, Maria Eleni Karaferi, and Yannis Pollalis. "Assessment of Knowledge and Attitudes of Healthcare Personnel Towards Artificial Intelligence Technologies in Greece: A Survey Study." *Hygiene* 5, no. 4 (2025): 44.
5. Gordon, Morris, Michelle Daniel, Aderonke Ajiboye, Hussein Uraiby, Nicole Y. Xu, Rangana Bartlett, Janice Hanson et al. "A scoping review of artificial intelligence in medical education: BEME Guide No. 84." *Medical teacher* 46, no. 4 (2024): 446-470.
6. Memon, S.S., Murad, S., Shah, S.A.R., Iqbal, Z., Saeed, R., Abid, J. Perception about artificial intelligence in medical education. Pak J Med Health Sci. 2023; 17(3):419. https://doi.org/10.53350/pjmhs2023173419
7. Sapci, A. Hasan, and H. Aylin Sapci. "Artificial intelligence education and tools for medical and health informatics students: systematic review." *JMIR Medical Education* 6, no. 1 (2020): e19285.
8. Edmonds, Victoria S., Krishanu Chatterjee, Marlene E. Girardo, Richard J. Butterfield III, and Cynthia M. Stonnington. "Evaluation of a novel wellness curriculum on medical student wellbeing and engagement demonstrates a need for student-driven wellness programming." *Teaching and Learning in Medicine* 35, no. 1 (2022): 52-64.
9. Buabbas, Ali Jasem, Brouj Miskin, Amar Ali Alnaqi, Adel K. Ayed, Abrar Abdulmohsen Shehab, Shabbir Syed-Abdul, and Mohy Uddin. "Investigating students' perceptions towards artificial intelligence in medical education." *In Healthcare*, vol. 11, no. 9, p. 1298. MDPI, 2023.

10. Page, Matthew J., Joanne E. McKenzie, Patrick M. Bossuyt, Isabelle Boutron, Tammy C. Hoffmann, Cynthia D. Mulrow, Larissa Shamseer et al. "The PRISMA 2020 statement: an updated guideline for reporting systematic reviews." *bmj* 372 (2021).
11. Jebreen, Kamel, Eqbal Radwan, Wafa Kammoun-Rebai, Etimad Alattar, Afnan Radwan, Walaa Safi, Walaa Radwan, and Mohammed Alajez. "Perceptions of undergraduate medical students on artificial intelligence in medicine: mixed-methods survey study from Palestine." *BMC medical education* 24, no. 1 (2024): 507.
12. Gillissen, Adrian, Tonja Kochanek, Michaela Zupanic, and Jan Ehlers. "Medical students' perceptions towards digitization and artificial intelligence: a mixed-methods study." In *Healthcare*, vol. 10, no. 4, p. 723. MDPI, 2022.
13. Allam, Ahmed Hafez, Nael Kamel Eltewacy, Yasmeen Jamal Alabdallat, Tarek A. Owais, Saif Salman, and Mahmoud A. Ebada. "Knowledge, attitude, and perception of Arab medical students towards artificial intelligence in medicine and radiology: a multi-national cross-sectional study." *European radiology* 34, no. 7 (2024): 1-14.
14. Jackson, Preetha, Gayathri Ponath Sukumaran, Chikku Babu, M. Christa Tony, Deen Stephano Jack, V. R. Reshma, Dency Davis, Nisha Kurian, and Anjum John. "Artificial intelligence in medical education-perception among medical students." *BMC Medical Education* 24, no. 1 (2024): 804.
15. Syeda, Laveeza H., Zoya Batool, Zeeshan Hayder, and Shabana Ali. "Medical undergraduate students' awareness and perspectives on artificial intelligence: A developing nation's context." *BMC Medical Education* 25, no. 1 (2025): 1060.
16. Teng, Minnie, Rohit Singla, Olivia Yau, Daniel Lamoureux, Aurinjoy Gupta, Zoe Hu, Ricky Hu et al. "Health care students' perspectives on artificial intelligence: countrywide survey in Canada." *JMIR medical education* 8, no. 1 (2022): e33390.
17. Truong, Nguyen Minh, Trung Quang Vo, Hien Thi Bich Tran, Hiep Thanh Nguyen, and Van Nu Hanh Pham. "Healthcare students' knowledge, attitudes, and perspectives toward artificial intelligence in the southern Vietnam." *Heliyon* 9, no. 12 (2023).
18. Sharma, Sonali, Neha Saboo, and Vaseem Naheed Baig. "Exploring undergraduate medical students' perspectives towards artificial intelligence in healthcare: a qualitative study from India." *JMA journal* 8, no. 3 (2025): 718-729.
19. Funer, F., S. Tinnemeyer, W. Liedtke, and S. Salloch. "Clinicians' roles and necessary levels of understanding in the use of artificial intelligence: A qualitative interview study with German medical students." *BMC Medical Ethics* 25, no. 1 (2024): 107.
20. Varma, Jonny R., Sherwin Fernando, Brian Y. Ting, Shahrukh Aamir, Rajesh Sivaprakasam, and Brian Yit Zheng Ting. "The global use of artificial intelligence in the undergraduate medical curriculum: a systematic review." *Cureus* 15, no. 5 (2023).
21. Mehta, Nishila, Vinyas Harish, Krish Bilimoria, Felipe Morgado, Shiphra Ginsburg, Marcus Law, and Sunit Das. "Knowledge of and attitudes on artificial intelligence in healthcare: a provincial survey study of medical students." *Medrxiv* (2021): 2021-01.
22. Blease, Charlotte, Anna Kharko, Michael Bernstein, Colin Bradley, Muiris Houston, Ian Walsh, Maria Hägglund, Catherine DesRoches, and Kenneth D. Mandl. "Machine learning in medical education: a survey of the experiences and opinions of medical students in Ireland." *BMJ health & care informatics* 29, no. 1 (2022): e100480.
23. Dave, Manas, and Neil Patel. "Artificial intelligence in healthcare and education." *British dental journal* 234, no. 10 (2023): 761-764.
24. Alkhaaldi, Saif MI, Carl H. Kassab, Zakia Dimassi, Leen Oyoun Alsoud, Maha Al Fahim, Cynthia Al Hageh, and Halah Ibrahim. "Medical student experiences and perceptions of ChatGPT and artificial intelligence: cross-sectional study." *JMIR Medical Education* 9, no. 1 (2023): e51302.
25. Pallivathukal, Renjith George, Htoo Htoo Kyaw Soe, Preethy Mary Donald, Renu Sarah Samson, Abdul Rashid Hj Ismail, and Abdul Rashid Hj Ismaile Hj Ismail. "ChatGPT for academic purposes: survey among undergraduate healthcare students in Malaysia." *Cureus* 16, no. 1 (2024).
26. Mondal, Himel, Juhu Kiran Krushna Karri, Swaminathan Ramasubramanian, Shaikat Mondal, Ayesha Juhi, and Pratima Gupta. "A qualitative survey on perception of medical students on the use of large language models for educational purposes." *Advances in Physiology Education* 49, no. 1 (2025): 27-36.
27. Abd-Alrazaq, Alaa, Rawan AlSaad, Dari Alhuwail, Arfan Ahmed, Padraig Mark Healy, Syed Latifi, Sarah Aziz, Rafat Damseh, Sadam Alabed Alrazak, and Javaid Sheikh. "Large language models in medical education: opportunities, challenges, and future directions." *JMIR medical education* 9, no. 1 (2023): e48291.
28. Swed, Sarya, Hidar Alibrahim, Nashaat Kamal Hamdy Elkalagi, Mohamad Nour Nasif, Mohammed Amir Rais, Abdulqadir J. Nashwan, Ahmed Aljabali et al. "Knowledge, attitude, and practice of artificial intelligence among doctors and medical students in Syria: a cross-sectional online survey." *Frontiers in artificial intelligence* 5 (2022): 1011524.
29. Syed, Wajid, and Mahmood Basil A. Al-Rawi. "Assessment of awareness, perceptions, and opinions towards artificial intelligence among healthcare students in Riyadh, *Saudi Arabia." Medicina* 59, no. 5 (2023): 828.
30. Barreiro-Ares, Andrés, Annia Morales-Santiago, Francisco Sendra-Portero, and Miguel Souto-Bayarri. "Impact of the rise of artificial intelligence in radiology: what do students think?." *International journal of environmental research and public health* 20, no. 2 (2023): 1589.
31. Knopp, Michelle I., Eric J. Warm, Danielle Weber, Matthew Kelleher, Benjamin Kinnear, Daniel J. Schumacher, Sally A. Santen, Eneida Mendonça, and Laurah Turner. "AI-enabled medical education: threads of change, promising futures, and risky realities across four potential future worlds." *JMIR Medical Education* 9 (2023): e50373.

32. Preiksaitis, Carl, and Christian Rose. "Opportunities, challenges, and future directions of generative artificial intelligence in medical education: scoping review." *JMIR medical education* 9, no. 1 (2023): e48785.
33. Tran, Michael, Chinthaka Balasooriya, Jitendra Jonnagaddala, Gilberto Ka-Kit Leung, Neeraj Mahboobani, Subha Ramani, Joel Rhee et al. "Situating governance and regulatory concerns for generative artificial intelligence and large language models in medical education." *NPJ Digital Medicine* 8, no. 1 (2025): 315.
34. Civaner, M. Murat, Yeşim Uncu, Filiz Bulut, Esra Giounous Chalil, and Abdülhamit Tatli. "Artificial intelligence in medical education: a cross-sectional needs assessment." *BMC Medical Education* 22, no. 1 (2022): 772.
35. Tung, Alvin Yong Zong, and Ley Wen Dong. "Malaysian medical students' attitudes and readiness toward AI (artificial intelligence): a cross-sectional study." *Journal of medical education and curricular development* 10 (2023): 23821205231201164.
36. Sit, Cherry, Rohit Srinivasan, Ashik Amlani, Keerthini Muthuswamy, Aishah Azam, Leo Monzon, and Daniel Stephen Poon. "Attitudes and perceptions of UK medical students towards artificial intelligence and radiology: a multicentre survey." *Insights into imaging* 11, no. 1 (2020): 14.
37. Zainal, Humairah, Xin Xiaohui, Julian Thumboo, and Fong Kok Yong. "Digital competencies for Singapore's national medical school curriculum: a qualitative study." *Medical Education Online* 28, no. 1 (2023): 2211820.
38. Li, Xinrui, Xiaodan Yan, and Han Lai. "The ethical challenges in the integration of artificial intelligence and large language models in medical education: A scoping review." *PLoS One* 20, no. 10 (2025): e0333411.
39. Mondal, Himel. "Ethical engagement with artificial intelligence in medical education." *Advances in physiology education* 49, no. 1 (2025): 163-165.
40. Hou, Zhitao, Jing Chen, and Hongwei Guo. "From "teaching by word and deed" to "intelligent mentorship": ethical reconsiderations of AI-enabled medical education—lessons from China." *Frontiers in Medicine* 12 (2025): 1754139.
41. Abdullah, Hafiz Muhammad Amad, Ghufran Ali Malkana, Masib Javed, Malik Muhammad Shahzaib, and Noor-i-Kiran Haris. "Exploring the ethical implications of ChatGPT in medical education: privacy, accuracy, and professional integrity in a cross-sectional survey." *Cureus* 16, no. 12 (2024).
42. Sharma, Vipul, Uddhave Saini, Varun Pareek, Lokendra Sharma, and Susheel Kumar. "Artificial intelligence (AI) integration in medical education: A pan-India cross-sectional observation of acceptance and understanding among students." *Scripta Medica* 54, no. 4 (2023): 343-352.
43. Stewart, Jonathon, Juan Lu, Nestor Gahungu, Adrian Goudie, P. Gerry Fegan, Mohammed Bennamoun, Peter Sprivulis, and Girish Dwivedi. "Western Australian medical students' attitudes towards artificial intelligence in healthcare." *PLoS One* 18, no. 8 (2023): e0290642.
44. Roveta, Annalisa, Luigi Mario Castello, Costanza Massarino, Alessia Francese, Francesca Ugo, and Antonio Maconi. "Artificial intelligence in medical education: A narrative review on implementation, evaluation, and methodological challenges." Ai 6, no. 9 (2025): 227.
45. Alam, Faiza, Mei Ann Lim, and Ihsan Nazurah Zulkipli. "Integrating AI in medical education: embracing ethical usage and critical understanding." *Frontiers in Medicine* 10 (2023): 1279707.
46. Ankamah, Samuel, Kwesi Gyesi, and Vivian Amponsah. "Awareness, knowledge, and attitude towards artificial intelligence: perspective of medical students in Ghana." *Information Development* 41, no. 3 (2025): 843-858.
47. Park, Christian J., H. Yi Paul, and Eliot L. Siegel. "Medical student perspectives on the impact of artificial intelligence on the practice of medicine." Current problems in diagnostic radiology 50, no. 5 (2021): 614-619.
48. Albusmait, Amna, Aseel AlSaleh, and Jamil Ahmed. "Medical Students' Perceptions and Attitude Toward the Use of Artificial Intelligence in Healthcare." Advances in Medical Education and Practice (2026): 1-9.
49. Sriram, Aadhitya, Kalpana Ramachandran, and Sriram Krishnamoorthy. "Artificial intelligence in medical education: transforming learning and practice." *Cureus* 17, no. 3 (2025).
50. Mousavi Baigi, Seyyedeh Fatemeh, Masoumeh Sarbaz, Kosar Ghaddaripouri, Maryam Ghaddaripouri, Atefeh Sadat Mousavi, and Khalil Kimiafar. "Attitudes, knowledge, and skills towards artificial intelligence among healthcare students: A systematic review." *Health science reports* 6, no. 3 (2023): e1138.
51. Wood, Elena A., Brittany L. Ange, and D. Douglas Miller. "Are we ready to integrate artificial intelligence literacy into medical school curriculum: students and faculty survey." Journal of medical education and curricular development 8 (2021): 23821205211024078.
52. Pucchio, Aidan, Raahulan Rathagirishnan, Natasha Caton, Peter J. Gariscsak, Joshua Del Papa, Jacqueline Justino Nabhen, Vicky Vo, Wonjae Lee, and Fabio Y. Moraes. "Exploration of exposure to artificial intelligence in undergraduate medical education: a Canadian cross-sectional mixed-methods study." *BMC medical education* 22, no. 1 (2022): 815.
53. Shishehgar, Sara, Pauline Murray-Parahi, Ethar Alsharaydeh, Sarah Mills, and Xianliang Liu. "Artificial intelligence in health education and practice: A systematic review of health students' and academics' knowledge, perceptions and experiences." International nursing review 72, no. 2 (2025): e70045.
54. Sami, Abdul, Fateema Tanveer, Khadeejah Sajwani, Nafeesa Kiran, Muhammad Ahsan Javed, Dilber Uzun Ozsahin, Khalid Muhammad, and Yasir Waheed. "Medical students' attitudes toward AI in education: perception, effectiveness, and its credibility." *BMC medical education* 25, no. 1 (2025): 82.

55. Rani, Sudha, Anita Kumari, Shreyasi C. Ekka, Ratnajeet Chakraborty, and Shreyasi Ekka. "Perception of medical students and faculty regarding the use of artificial intelligence (AI) in medical education: a cross-sectional study." *Cureus* 17, no. 1 (2025).
56. Busch, Felix, Lena Hoffmann, Daniel Truhn, Esteban Ortiz-Prado, Marcus R. Makowski, Keno K. Bressem, and Lisa C. Adams. "Global cross-sectional student survey on AI in medical, dental, and veterinary education and practice at 192 faculties." *BMC medical education* 24, no. 1 (2024): 1066.
57. Kansal, Rohin, Ashvind Bawa, Arpit Bansal, Shubam Trehan, Kashish Goyal, Naresh Goyal, and Kashish Malhotra. "Differences in knowledge and perspectives on the usage of artificial intelligence among doctors and medical students of a developing country: a cross-sectional study." *Cureus* 14, no. 1 (2022).
58. Chheang, Vuthea, Shayla Sharmin, Rommy Márquez-Hernández, Megha Patel, Danush Rajasekaran, Gavin Caulfield, Behdokht Kiafar, Jicheng Li, Pinar Kullu, and Roghayeh Leila Barmaki. "Towards anatomy education with generative AI-based virtual assistants in immersive virtual reality environments." In 2024 IEEE international conference on artificial intelligence and eXtended and virtual reality (AIxVR), pp. 21-30. IEEE, 2024.
59. Xu, Zhiyi. "AI in education: Enhancing learning experiences and student outcomes." Applied and Computational Engineering 51, no. 1 (2024): 104-111.
60. Susilo, Tarsisius. "The Role of Artificial Intelligence in Personalizing Learning for Each Student." JILTECH: *Journal International of Lingua & Technology* 3, no. 2 (2024).
61. Khakpaki, Aliasghar. "Advancements in artificial intelligence transforming medical education: a comprehensive overview." Medical education online 30, no. 1 (2025): 2542807.
62. Thompson, Rasheed AM, Yash B. Shah, Francisco Aguirre, Courtney Stewart, Costas D. Lallas, and Mihir S. Shah. "Artificial intelligence use in medical education: best practices and future directions." *Current Urology Reports* 26, no. 1 (2025): 45.
63. Xu, Tianhui, Huiting Weng, Fang Liu, Li Yang, Yuanyuan Luo, Ziwei Ding, and Qin Wang. "Current status of ChatGPT use in medical education: potentials, challenges, and strategies." *Journal of Medical Internet Research* 26 (2024): e57896.
64. Zhang, Mudan, Yan Yu, Baofei Sun, Chaolun Xiao, Jingxi Yang, Zijiang Yu, and Dan Yang. "Investigating Clinical-Relevant learning in the anatomy curriculum: perspectives and effectiveness for undergraduate medical students." *Journal of Medical Education and Curricular Development* 12 (2025): 23821205251328952.
65. Rezazadeh, Hossein, Ali Madadi Mahani, and Mahla Salajegheh. "Insights Into the Future: Assessing Medical Students' Artificial Intelligence Readiness-A Cross-Sectional Study at Kerman University of Medical Sciences (2022)." *Health Science Reports* 8, no. 5 (2025): e70870.
66. Liu, David Shalom, Jake Sawyer, Alexander Luna, Jihad Aoun, Janet Wang, Lord Boachie, Safwan Halabi, and Bina Joe. "Perceptions of US medical students on artificial intelligence in medicine: mixed methods survey study." *JMIR Medical Education* 8, no. 4 (2022): e38325.
67. Al Shahrani, Abeer, Norah Alhumaidan, Zeena AlHindawi, Abdullah Althobaiti, Khalid Aloufi, Rasil Almughamisi, and Ahad Aldalbahi. "Readiness to embrace artificial intelligence among medical students in Saudi Arabia: a national survey." In Healthcare, vol. 12, no. 24, p. 2504. MDPI, 2024.
68. Lee, Juehea, Annie Siyu Wu, David Li, and Kulamakan Kulasegaram. "Artificial intelligence in undergraduate medical education: a scoping review." *Academic Medicine* 96, no. Supplement_2 (2021): S62-S70.
69. Al Saad, Mouna M., Amin Shehadeh, Salem Alanazi, Monerah Alenezi, Hana Eid, Mohammed Saif Alfaouri, Sultan Aldawsari, and Rawan Alenezi. "Medical students' knowledge and attitude towards artificial intelligence: an online survey." *The Open Public Health Journal* 15, no. 1 (2022).
70. Grunhut, Joel, Oge Marques, and Adam TM Wyatt. "Needs, challenges, and applications of artificial intelligence in medical education curriculum." *JMIR medical education* 8, no. 2 (2022): e35587.
71. Kin, Taichi. "Virtual reality surgical simulations using fusion three-dimensional images." No Shinkei geka. Neurological Surgery 52, no. 2 (2024): 240-247.
72. Ngo, Brandon, Diep Nguyen, and Eric vanSonnenberg. "The cases for and against artificial intelligence in the medical school curriculum." Radiology: Artificial Intelligence 4, no. 5 (2022): e220074.
73. Dumić-Čule, Ivo, Tin Orešković, Boris Brkljačić, Mirjana Kujundžić Tiljak, and Stjepan Orešković. "The importance of introducing artificial intelligence to the medical curriculum–assessing practitioners' perspectives." *Croatian medical journal* 61, no. 5 (2020): 457-464.
74. Kröplin, Juliane, Tobias Huber, Christian Geis, Benedikt Braun, and Tobias Fritz. "eSurgery—digital transformation in surgery, surgical education and training: survey analysis of the status quo in Germany." European Surgery 54, no. 5 (2022): 249-258.
75. Karaca, Ozan, S. Ayhan Çalışkan, and Kadir Demir. "Medical artificial intelligence readiness scale for medical students (MAIRS-MS)–development, validity and reliability study." *BMC medical education* 21, no. 1 (2021): 112.
76. Luo, Jiani, Qiyun Peng, Huiling Cao, Wenxuan Li, and Shenglan Tan. "Medical undergraduate students' readiness and anxiety toward artificial intelligence: a systematic review and meta-analysis." *BMC Medical Education* (2025).
77. Grunhut, Joel, Adam TM Wyatt, and Oge Marques. "Educating future physicians in artificial intelligence (AI): an integrative review and proposed changes." *Journal of Medical Education and Curricular Development* 8 (2021): 23821205211036836.

78. Ghorashi, Nima, Ahmed Ismail, Pritha Ghosh, Anton Sidawy, Ramin Javan, and Nima S. Ghorashi. "AI-powered chatbots in medical education: potential applications and implications." *Cureus* 15, no. 8 (2023).
79. Alli, Sauliha Rabia, Soaad Qahhār Hossain, Sunit Das, and Ross Upshur. "The potential of artificial intelligence tools for reducing uncertainty in medicine and directions for medical education." *JMIR Medical Education* 10, no. 1 (2024): e51446.
80. Ma, Songhua, Qing Zhou, and Huiqun Wu. "Differences and Trends of Artificial Intelligence in Medical Education: A Comparative Bibliometric Analysis Between China and the International Community." *Advances in Medical Education and Practice* (2026): 1-11.
81. Jacobs, Sarah Marie, Neva Nicole Lundy, Saul Barry Issenberg, and Latha Chandran. "Reimagining core entrustable professional activities for undergraduate medical education in the era of artificial intelligence." *JMIR medical education* 9 (2023): e50903.
82. Seneviratne, Thilanka, Kaumudee Kodikara, Isuru Abeykoon, and Wathsala Palpola. "Perception of Medical Undergraduates on Artificial Intelligence in medical education: qualitative exploration." *JMIR Medical Education* 11, no. 1 (2025): e73798.
83. Khan, Muhammad Junaid, Mehreen Lajber, Nazish Bilal, Sana Khan, and Aziz Ahmad. "The barriers and solution to Artificial intelligence adoption in medical education: a qualitative study." *Journal of Saidu Medical College* 14, no. 4 (2024): 341-347.
84. Güven, Gamze Özbek, Şerife Yilmaz, and Feyza Inceoğlu. "Determining medical students' anxiety and readiness levels about artificial intelligence." Heliyon 10, no. 4 (2024).
85. Faihs, Valentina, Christina Figalist, Eileen Bossert, Katja Weimann, Pascal O. Berberat, and Marjo Wijnen-Meijer. "Medical students and their perceptions of digital medicine: a question of gender?." *Medical Science Educator* 32, no. 5 (2022): 941-946.
86. Duan, Shuo, Chunyu Liu, Tianhua Rong, Yixin Zhao, and Baoge Liu. "Integrating AI in medical education: a comprehensive study of medical students' attitudes, concerns, and behavioral intentions." *BMC medical education* 25, no. 1 (2025): 599.
87. Naseer, Muhammad Ahsan, Sana Saeed, Azam Afzal, Sobia Ali, and Marib Ghulam Rasool Malik. "Navigating the integration of artificial intelligence in the medical education curriculum: a mixed-methods study exploring the perspectives of medical students and faculty in Pakistan." *BMC Medical Education* 25, no. 1 (2025): 273.
88. Kawakami, Chihiro, Osamu Nomura, Miyuki Takahashi, Ritsuki Takaha, Takayasu Ito, Hiroaki Ushikoshi, and Takuya Saiki. "Rapidly rising preference among new-entry medical students for using generative artificial intelligence in reflective reports." *JMA journal* 8, no. 2 (2025): 465-469.
89. Charow, Rebecca, Tharshini Jeyakumar, Sarah Younus, Elham Dolatabadi, Mohammad Salhia, Dalia Al-Mouaswas, Melanie Anderson et al. "Artificial intelligence education programs for health care professionals: scoping review." *JMIR Medical Education* 7, no. 4 (2021): e31043.
90. Shi, Xiaokang, Zewu Jiang, Li Xiong, Ka-Chun Siu, and Zhen Chen. "Utilization of AI Among Medical Students and Development of AI Education Platforms in Medical Institutions: Cross-Sectional Study." *JMIR human factors* 13 (2026): e81652.
91. Khanagar, Sanjeev, Mohammad Alkathiri, Rakan Alhamlan, Khalid Alyami, Majed Alhejazi, and Ahmed Alghamdi. "Knowledge, attitudes, and perceptions of dental students towards artificial intelligence in Riyadh, *Saudi Arabia*." Med Sci 25, no. 114 (2021): 1857-1867.
92. Pizzolla, Ilaria, Rania Aro, Pierre Duez, Bruno De Lièvre, and Giovanni Briganti. "Integrating artificial intelligence into medical education: lessons learned from a Belgian initiative." *Journal of Interactive Learning Research* 34, no. 2 (2023): 401-424.
93. Crotty, Erin, Ajesh Singh, Noirin Neligan, Crispen Chamunyonga, and Christopher Edwards. "Artificial intelligence in medical imaging education: Recommendations for undergraduate curriculum development." *Radiography* 30 (2024): 67-73.
94. Aluko, Henry Adeyemi, Ayodele Aluko, Goodness Amaka Offiah, Funke Ogunjimi, Akinseye Olatokunbo Aluko, Funmi Margareth Alalade, Ikechukwu Ogeze Ukeje, and Chinyere Happiness Nwani. "Exploring the effectiveness of AI-generated learning materials in facilitating active learning strategies and knowledge retention in higher education." *International Journal of Organizational Analysis* 34, no. 4 (2026): 1243-1267.
95. Hu, Ricky, Kevin Y. Fan, Prashant Pandey, Zoe Hu, Olivia Yau, Minnie Teng, Patrick Wang, Toni Li, Mishal Ashraf, and Rohit Singla. "Insights from teaching artificial intelligence to medical students in Canada." Communications medicine 2, no. 1 (2022): 63.
96. Ejaz, Hamza, Hari McGrath, Brian LH Wong, Andrew Guise, Tom Vercauteren, and Jonathan Shapey. "Artificial intelligence and medical education: A global mixed-methods study of medical students' perspectives." *Digital health* 8 (2022): 20552076221089099.
97. Jha, Nisha, Pathiyil Ravi Shankar, Mohammed Azmi Al-Betar, Rupesh Mukhia, Kabita Hada, and Subish Palaian. "Undergraduate medical students' and interns' knowledge and perception of artificial intelligence in medicine." Advances in Medical Education and Practice 13 (2022): 927.

Citation: Dimitrios Karaferis. et,al. Investigating the perspectives, awareness, and preparedness of Medical Undergraduate Students concerning the usage of digital and AI elements in health systems: A review of research. *J. Virol. Vaccin.* Vol. 5 Iss. 1. (2026) DOI: 10.58489/2836-6387/009