







# Artificial intelligence literacy among healthcare professionals and students: A systematic review

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## ABSTRACT

**Introduction:** In the digital age, since the application of artificial intelligence (AI) is increasingly penetrating the world, the cultivation of AI literacy has become increasingly important for everyone. This systematic review investigated the level of AI literacy among healthcare professionals and students.

**Material and Methods:** We searched the databases PubMed, Embase, Scopus, and Web of Science for relevant material. The evidence gathered from the studies included in this systematic review was reported in this study using preferred reporting items for systematic reviews and meta-analyses (PRISMA). Studies that assessed the level of AI literacy among medical and healthcare professionals and students met the inclusion criteria for this study. The quality of the included study for this review was assessed using the analytical cross-sectional critical assessment checklist developed by the Joanna Briggs Institute (JBI). The same standard checklist was used for data extraction.

**Results:** Of the 10 included studies, 4 (40%) reported a low level of preparation, knowledge, and literacy. In a study, it was also shown that radiologists had acceptable literacy about AI, and it seems that they had a better study of this field compared to other specialists. Another study showed that initially the level of AI literacy was not acceptable but improved significantly after training. Two studies also hailed AI's contribution to improving healthcare.

**Conclusion:** Evidence from this review indicated that half of the studies on the AI literacy of professionals and students were very low, and other included studies also reported the basic literacy of AI acceptably. Finally, in all included studies, AI training courses and their application in healthcare were considered necessary for professionals and students, and they were trying to improve the educational infrastructure.

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## INTRODUCTION

The primary goal of artificial intelligence (AI) is to build intelligent computers that are capable of understanding computations and doing activities that call for human intellect, such as precise speech

recognition, visual perception, quick decision-making, and language translation. AI is currently used in our daily lives to an increasingly higher level. AI is therefore no longer a future concept. AI is increasingly being used in the medical field [1]. Deep learning (DL) and machine learning (ML) are two

subcategories of AI that the health sector is investigating [2]. The field of radiology has been the biggest user of AI systems. However, there are other instances of its application in other fields, such as medicine, neurology, pathology, psychiatry, cardiology, rehabilitation, dermatology, and ophthalmology [3-10].

DL refers to an area of artificial intelligence that utilizes a layered algorithmic architecture for data processing [11]. DL provides a range of apps that aid in identifying complex but subtle patterns in pictures. This kind of ability may be used in model-oriented healthcare domains like radiology, pathology, and dermatology for image-based automated diagnosis [4-6, 11].

As AI continues to advance, its uses will go beyond picture categorization and into fields like psychiatry's natural language processing and cardiology's signal processing [12]. It is expected that in the future, AI-assisted systems will be able to carry out specialized duties including patient screening and test referrals, as well as becoming more autonomous and recommending possible therapeutic interventions [13].

In the digital age, since the application of AI is increasingly penetrating the world, the cultivation of AI literacy has become increasingly important for everyone [14, 15]. For example, some UK medical schools offer limited training opportunities in healthcare AI. However, the true prevalence of such training and the level of AI literacy among the UK medical student population remains unknown. The increasing pervasiveness of AI-related technologies shows that the time has come for every society to educate its citizens about AI.

Additionally, as the field of healthcare AI gains momentum, it is becoming increasingly clear that increased awareness is needed along with AI-based training for medical and healthcare practitioners and students. A national government review was conducted in 2019 on the same topic and clearly emphasized the importance of arming the current and future clinical workforce with the necessary skills to work with new digital tools, including those underpinning AI [16].

Meanwhile, the recent increase in interest in training healthcare students in AI reflects the growing integration of AI applications in education, research, and clinical care. The Royal College of Physicians, Surgeons of Canada, and the Association of American Medical Colleges have recommended training for healthcare professionals related to AI, including training on data sourcing and stewardship, AI ethics, critical evaluation, and interpretation of AI applications in health [4, 17, 18]. It is clear that the need to properly use and apply AI while enjoying its benefits and protecting your privacy requires proper

training. People need to acquire specific types of AI-related knowledge, skills, and values. Such basic AI literacy is increasingly necessary for effective collaboration between humans and machines in life, learning, and the workplace [19].

Researchers have previously conducted reviews of attitudes toward AI education among healthcare students [20]. However, at the current stage, few attempts have been made to start teaching healthcare students and professionals the key concepts of AI. Most approaches are focused on algorithms and programming for AI training [21-25]. Accordingly, most computer science approaches target students with computer science-related fields [26].

However, the World Health Organization warned that healthcare professionals need to understand how AI works [27]. Future healthcare workers will use AI concepts and algorithms based on their understanding [28]. This is important because AI is not a magical tool that can be taken for granted, and poor implementation of AI projects can lead to misdiagnoses that harm patients, as reported in some studies [29]. Previous studies have highlighted communication gaps among healthcare workers regarding AI, such as poor data storage, which may hinder the efficient and appropriate use of this technology [28].

Healthcare workers with AI knowledge are expected to replace those without such knowledge in the future [30]. Apart from the fact that AI in medicine is an exciting and fast-paced field of research where future doctors, specialists, and scientists can conduct interesting experiments, knowing how it works and being able to interpret its results is also a prerequisite for their future careers. In addition, AI permeates many daily clinical tasks as a supporting entity [31], which will greatly influence the skills required for future performance [32].

Despite the increasing contribution of AI in healthcare and research on the level of literacy of healthcare professionals and students towards AI, few systematic reviews integrate the best evidence and provide an overview of the field. Therefore, this systematic review investigated the level of AI literacy among healthcare professionals and students.

## MATERIAL AND METHODS

### Study design

The evidence gathered from the studies included in this systematic review was reported in this study using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [33].

### Strategic search

On October 4, 2023, we searched the databases

PubMed, Embase, Scopus, and Web of Science for relevant material. The search method for each database is displayed in Appendix 1. The databases were searched using the following Medical Subject Headings and Emtree keywords and terms: (AI or "artificial intelligence" or "machine learning" or "intelligence, artificial" or "computational intelligence" or "intelligence, computational" or "machine intelligence" or "intelligence, machine" or "computer reasoning" or "reasoning, computer" or "AI (artificial intelligence)" ) and (literacy or skills or competence or fluency) or ("AI literacy" or "artificial intelligence literacy" or "AI skills" or "artificial intelligence skills" or "AI competence" or "artificial intelligence competence" or "AI fluency" or "artificial intelligence fluency") and (health or medical or medicine or rehabilitation).

### Eligibility criteria

Studies that assessed the level of AI literacy among medical and healthcare professionals and students met the inclusion criteria for this study. However, papers whose target audience was students other than those studying medicine and healthcare, such as those studying technical and computer science, for whom the complete text was unavailable, as well as those written in a language other than English, were eliminated from the study.

### Data extraction and synthesis

All documents were acquired using a systematic search, and duplicate documents were eliminated before this examination. Titles and abstracts were independently reviewed for eligibility using the criteria. Articles that did not meet the criteria for inclusion were not included in the review. The full texts were then retrieved and assessed in accordance with the criteria for eligibility by two distinct researchers. When there was a tie, the third author made the decision after discussions to resolve the conflict. The same standard checklist was used for data extraction. Among the data items contained in this form are the study reference, study nation, publication year, participant characteristics (number of participants and their field of study), study objectives, and study outcomes.

### Quality assessment

The quality of the research submitted for this review was assessed using the analytical critical assessment checklist developed by the Joanna Briggs Institute (JBI) [34]. In order to evaluate the quality of these studies, the research explicitly gathered 8 questions. The following were the topics covered by the questions in this checklist: a sample inclusion criterion, study subjects, the setting, valid and reliable measurement tools (including the validity and reliability of questionnaires), standard

measurement criteria, identification of confounding factors, dealing with confounding factors strategies, valid measured outcomes, and appropriate statistical analysis. There were four categories for the responses to the questions: yes, no, unclear, and not applicable. The reaction to a question was either stamped as 1 or 0, depending on whether it was yes or no, unclear, or not pertinent. So, each included study could only get a quality score of 8, and the exclusion only applies if the study's quality score is underneath 5.

## RESULTS

Fig 1 displays 9,542 documents that were located through database searches. After duplications (1966) were removed, 7576 studies' titles and abstracts were reviewed. After the titles and abstracts of the studies were checked for relevance to the study's goals, 7546 studies in total were discarded. Then, 30 articles were picked for full-text analysis. In the end, 10 studies that met the criteria for inclusion were included in the review.

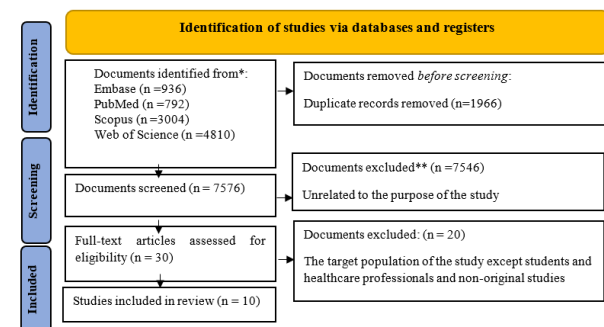


Fig 1: Flowchart of study selection and screening

### Quality assessment

According to the quality evaluation findings provided in Table 1, which reveal that there was no discernible bias in the studies, we only included high-quality studies in our analysis. One of the most prevalent problems in these investigations was the inability to recognize confounding factors and create mitigation plans for them.

### Study characteristics

Tables 2 and 3 list the specifications of all the included studies. According to Fig 2, of the ten included studies, two studies (20%) were conducted in Saudi Arabia [34, 35], two studies (20%) were conducted in England [36, 37], two studies (20%) were conducted in Canada [11, 38], and other studies were conducted in the United States (10%) [25], Italy (10%) [24], Spain (10%) [39], and Taiwan (10%) [40]. Fields of study for healthcare students and professionals include six fields of medicine [34, 36, 40], dentistry [34, 39], radiology [35], laboratory

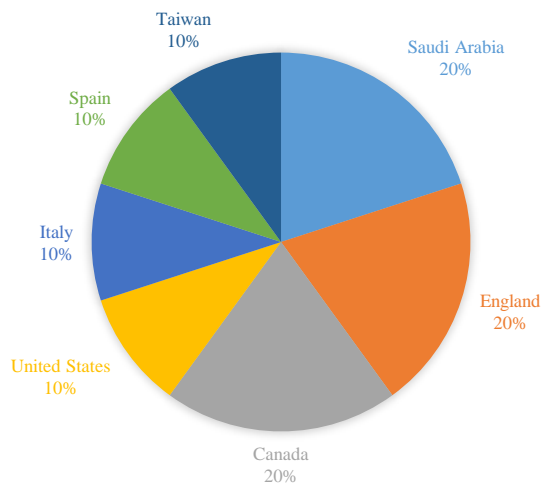
[41], ophthalmology [37], radiation therapy ecologists, and medical physics [38], and two studies include healthcare fields in general [11, 42]. The total

sample size in the included studies was 3892 participants. The sample size was between 15 and 2167 participants.

**Table 1: Summary of the articles' quality ratings using the JBI critical appraisal methodology**

Study/ Questions	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Score
Aboalshamat, 2022, Saudi Arabia [34]	Y	Y	Y	Y	N	N	Y	Y	6
Alelyani, 2021, Saudi Arabia [35]	Y	Y	Y	Y	N	N	Y	Y	6
Bellini, 2022, Italy [41]	Y	Y	Y	Y	N	N	Y	Y	6
Teng, 2022, Canada [11]	Y	Y	Y	Y	N	N	Y	Y	6
Russell, 2023, America [42]	Y	Y	Y	Y	N	N	Y	Y	6
Ejaz, 2022, 48 countries around the world [36]	Y	Y	Y	Y	N	N	Y	Y	6
Yang, 2019, Taiwan [40]	Y	Y	Y	Y	N	N	Y	Y	6
Suárez, 2022, Spain [39]	Y	Y	Y	Y	N	N	Y	Y	6
Constantin, 2023, England [37]	N	Y	Y	Y	N	N	Y	Y	5
Gillan, 2019, Canada [38]	Y	Y	Y	Y	N	N	Y	Y	6

\*Abbreviations: JBI, Joanna Briggs Institute; Q, question, N, no; NA, not/applicable; U, unclear; Y, yes; Score: the quality assessment score ranged from 0 to 8 based on each question of the JBI checklist



**Fig 2: Distribution of countries in included studies**

**Table 2: Characteristics of participants in all included studies**

Source (first author, year, country)	Study method	Number of participants	Field of participants
Aboalshamat, 2022, Saudi Arabia [34]	Cross-sectional study	334	Medicine and dentistry
Alelyani, 2021, Saudi Arabia [35]	Cross-sectional study	714	Radiology
Bellini, 2022, Italy [41]	Cross-sectional study	227	Biologist, laboratory specialist and managers
Teng, 2022, Canada [11]	Cross-sectional study	2167	Healthcare
Russell, 2023, America [42]	Interview study	15	Healthcare
Ejaz, 2022, 48 countries around the world [36]	Mixed-methods	128	Medicine
Yang, 2019, Taiwan [40]	Prospective pilot study	72	Medical interns
Suárez, 2022, Spain [39]	Descriptive cross-sectional	193	Dentistry
Constantin, 2023, England [37]	Web-based interview study	18	Ophthalmology
Gillan, 2019, Canada [38]	Cross-sectional study	24	Radiation oncologists, medical physicists, treatment planners, and radiation therapists provide treatment

**Table 3: Summary of study characteristics from all included studies**

Source (first author, year, country)	Study goal	Results
Aboalshamat, 2022, Saudi Arabia [34]	Assessing readiness levels for AI among medical and dental professionals in Saudi Arabia	Participants had low levels of readiness for AI, although dental professionals had better literacy scores. Based on the low readiness levels measured in this study, medical and dental professionals are not yet ready for AI. While dental professionals had better preparedness scores than medical professionals, it is recommended that educational organizations and hospitals include AI modules and practical training at undergraduate and postgraduate levels.
Alelyani, 2021, Saudi Arabia [35]	Assessing the attitude of the radiology community in Saudi Arabia towards AI applications	Most of the participants (61.2%) had read or heard about the role of AI in radiology. The level of reported AI knowledge was moderate and acceptable. The participants had an acceptable level of AI knowledge. Human-machine interaction will be one of the most important skills in the future, and therefore AI applications should be included in the curriculum of medical students.
Bellini, 2022, Italy [41]	Evaluation of the level of expertise, knowledge, and interest of Italian clinical laboratory specialists in the field of Big Data and Artificial Intelligence (BAI) and its applications in laboratory medicine (LM).	Only 20% of respondents stated that they had a good understanding of BAI, and an even smaller percentage (12%) felt that they had a competent level in this area. The overall results offer the opportunity to understand the related shortcomings in the implementation of AI in LM. Practitioners should spend time learning the basics of these new technologies in order to evaluate clinical trial opportunities.
Teng, 2022, Canada [11]	Investigating and identifying gaps in Canadian healthcare students' knowledge of AI, how these students differ across disciplines in their knowledge and views of AI	More than half of the respondents did not know what AI was (1107/2167, 51.08%) or had a misunderstanding of it (676/2167, 31.2%). Canadian healthcare students were cautiously optimistic about the role of AI in their fields. However, many felt uninformed about the matter. Healthcare students in different programs identified different curricular needs, and such program-specific needs should be considered when integrating the AI curriculum.
Russell, 2023, America [42]	Defining AI-related clinical competencies for healthcare professionals, exploring future applications of healthcare AI technologies, and organizational responsibilities required for oversight and management	Six clinical competencies for AI were identified that can be used to guide future teaching and learning programs in maximizing the potential benefits of AI-based tools and reducing potential harms. Six AI-related clinical competencies for healthcare professionals were included: 1. Basic knowledge of AI; 2. Social and ethical implications of AI; 3. Workflow analysis for AI-based tools; 4. AI-enhanced clinical encounters; 5. Evidence-based assessment of AI-based tools; 6. Practice-based training and improvement in relation to AI-based instruments
Ejaz, 2022, 48 countries around the world [36]	Reporting on the state of AI medical education globally	There was support for including AI education in mainstream curricula around the world, but few students had received AI education. Medical students from all countries should be offered AI training as part of their curriculum to develop skills and knowledge about AI to ensure a patient-centric digital future in medicine.
Yang, 2019, Taiwan [40]	Investigating the improvement of skill training of medical interns with a new AI-based intervention program for suturing and ligature skills.	Literacy level was high after training with a new intervention program based on AI. This study showed promising effects of incorporating an expert-led training course with an AI system into the routine surgical curriculum. Increased training frequency with an AI system improved medical interns' confidence and performance in suturing skills.
Suárez, 2022, Spain [39]	Creating and evaluating a virtual patient through an AI chatbot to develop pulp pathology diagnostic skills in dental students	A total of 193 students participated. A large majority of students were satisfied with the interaction (mean 4.36), and fifth-year students gave a better score to the interaction and showed higher satisfaction values. Students who made the correct diagnosis evaluated the technology more positively. The results of this study show the usefulness of simulating a VP with AI by giving students the possibility of clinical practice and also providing an attractive and personal experience to students due to the user interface and natural language used, without underestimating the economic costs. Incorporating this technology into dental curricula has positive value for students and also ensures their training and adaptation to new technological developments.
Constantin, 2023, England [37]	Identifying ophthalmologists' expectations and concerns regarding the National Image Research Repository and their use of AI-based decision support and gathering their suggestions for improving eye healthcare	A strong desire to use AI to improve healthcare was found, along with concerns about training, costs, responsibilities, skill retention, data sharing, and disruption to professional practice.
Gillan, 2019, Canada [38]	Assessing radiation medicine professionals' perceptions of clinical and professional risks and benefits and evolving roles and responsibilities with AI	In the absence of AI-related tools, trained employees form complex views about their value and impact. The introduction of AI strategies in radiation medicine will require changes in practice that will have ripple effects across many aspects of care and will require professional groups to adjust their roles in response. To plan more responsibly for such a complex intervention, it is crucial to consider these professional groups and their educational needs in terms of technological literacy and new workflow models and empower them to participate in the leadership of change.



### AI literacy rates among healthcare professionals and students

According to Fig 3, of the 10 included studies, 4 (40%) reported a low level of preparation, knowledge, and awareness [11, 34, 36, 41]. In a study, it was also shown that radiologists had acceptable literacy about AI, and it seems that they had a better study of this field compared to other specialists [35]. Another study showed that initially the level of AI literacy was not acceptable but improved significantly after training [40]. Two studies also hailed AI's contribution to improving healthcare [37, 39]. Another study identified cases of clinical merit for AI that could be used to guide future teaching and learning programs in maximizing the potential benefits of AI-based tools and reducing potential harm [42]. In another study, professional groups were required to adjust their roles in AI practice [38].

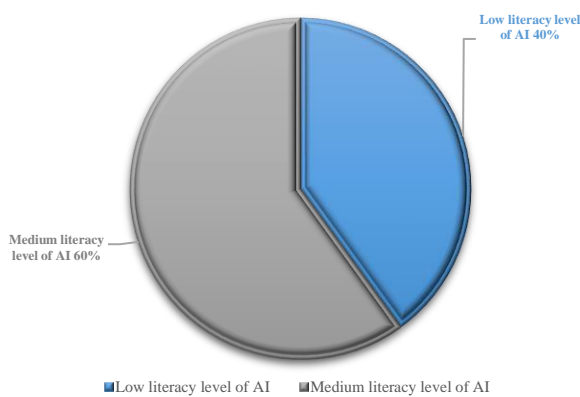


Fig 3: The level of AI literacy in included studies

## DISCUSSION

### Principal findings

Evidence from this systematic review shows that the majority of healthcare professionals and students were motivated to use AI to improve healthcare. However, few participants received adequate training in this field and had limited literacy in the use of AI. Ten studies met all the requirements for inclusion in this review. The level of literacy, education, and skills of healthcare students towards AI were investigated in the studies. The JBI checklist criteria indicated that almost all studies had moderate to high-quality evidence.

Among healthcare professionals and students, radiologists had the most literacy in using AI [35]. According to the findings of this study, increasing the frequency of training with AI systems and including the training course in the courses of healthcare students will have promising effects in clinical work, and human-machine interaction will be one of the most important skills in the future. AI should also be

highlighted as an integral advancement in healthcare that should be addressed by medical and healthcare professionals to increase their preparedness. This can help the next generation of medical professionals' cope with the age of data science and fit into the future AI ecosystem [13, 43, 44].

Aboalshamat et al. found that dental professionals were more prepared to work with AI in a clinical setting than medical professionals. But in general, the overall level of preparation among the participants was not satisfactory. This indicates that medical and dental professionals did not have sufficient literacy and preparation to use AI at this time [34].

Alelyani also showed in his study in Saudi Arabia that radiologists had an acceptable level of knowledge about AI technology. So, 80% of the respondents agreed that AI technologies should be validated in an established clinical setting [35]. In another study in Italy, Bellini showed that an overwhelming majority of participants (95%, 162 out of 170 respondents) expressed interest in training related to the use of BAI in laboratories. Most respondents said they would like to improve their literacy and skills in data management (35%) or data analysis (37%), while a third said they would benefit from taking a course in this area (28%).

The findings of this study showed a general lack of hardware and software infrastructure, a lack of personal computers, a lack of corporate Wi-Fi networks, and a low level of subjective satisfaction regarding hardware and software equipment [41]. Teng stated that healthcare students were generally cautiously optimistic about AI in their fields, although more than half of healthcare students indicated that they did not know what AI was or how it might be relevant to their field of work. In general, healthcare students feel unprepared and uneducated about AI, which may have contributed to their fear and anxiety about the topic [11].

Similar mixed feelings have been previously expressed by MD students from the United Kingdom [45] and by health professionals in France and the United States [46, 47]. A 2020 European survey found that only one-third of surveyed medical students claimed to have basic knowledge of AI [45]. A 2021 survey of medical students in Ontario found that respondents believed they understood what AI meant. However, when asked about specific terms related to AI, such as machine learning or neural networks, students did not understand them [48]. Healthcare workers seem to hope that the integration of AI will bring about improvements in diagnostic accuracy [49], patient monitoring [46], and reductions in medical errors [50].

Concerns regarding the integration of AI in healthcare may be attributed to the potential to replace health professionals [51] and additional

knowledge requirements in their fields [52]. Medical communities should address concerns about how to test AI software for therapeutic efficacy and safety before implementing a large-scale clinical application of AI [53]. Today, the superiority of computers over humans is not debatable, but this question revolves around how medicine can benefit from these capabilities [54].

With the development and growth of AI in various aspects of healthcare, its impact on people on the front line of care is inevitable, but this issue has been less noticed until today. An AI-friendly healthcare education program is therefore essential because future healthcare providers will likely be responsible for overseeing the algorithmic interpretation of patient healthcare data [55]. One of the important goals of the literacy course is to empower participants by increasing their ability to understand, interact with, and communicate with AI applications on a digital course [56].

According to Mäkinen, the term "people empowerment" refers to providing people with the tools they need to better control their lives and expand their communication skills. The goal of AI literacy is to provide people with new abilities and ways to participate in a digital society. This understanding refers to a goal of empowerment through AI or a goal of enhancing "assurance through interaction with AI". Several similar concepts, such as "digital empowerment and programming empowerment," have been proposed [57]. These terms describe the means of empowering people in different fields. Kong et al. suggested that programming empowerment has four main components: planning self-efficacy, meaningfulness, impact, and creative self-efficacy, to understand programming empowerment [58].

In another study on the concept of empowering AI, the components of AI self-efficacy—meaningfulness, influence, and creative self-efficacy—were used [56]. In general, the value of AI literacy is widely recognized because it is useful for lifelong learning and can be used in many everyday situations [59]. Additionally, participants who perceive AI as meaningful are likely to exert more effort to excel and feel empowered. Students' understanding of AI literacy and its social effects is important because a person who feels that interaction with AI creates more impact tends to be more intrinsically motivated to learn related skills. Frymier states that participants can be motivated to learn AI skills after becoming aware of their social impact [60].

Empowering AI literacy education for professionals and students has the potential to not only enable the use of existing technology but also inspire future technology producers [61]. In summary, the results of this review indicated that half of the studies on the AI literacy of professionals and students were very low,

and other studies also reported the basic literacy of AI acceptably. Finally, in all included studies, AI training courses and their application in healthcare were considered necessary for professionals and students, and they were trying to improve the educational infrastructure. In this regard, technologies such as mobile health interventions, digital games, simulation tools, virtual reality, and telemedicine can be used for more useful and effective training [62-70].

### Strengths and weaknesses

This systematic review has many benefits. First, we followed the rules for difficult systematic review procedures [21]. Second, the quality of the evidence from each included study was assessed using the JBI assessment criteria. This increased the quality of the included studies' transparency. Third, this evaluation offers insightful information to those who shape educational policy in the area of AI literacy in healthcare and medicine. However, this study could have had certain drawbacks. Limited studies have explicitly examined AI literacy among professionals and students.

Therefore, due to the lack of evidence found, the proof of these results needs more investigation. In addition, studies used different questionnaires and questions to measure the level of AI literacy of experts and students. For example, one study reports a high level of AI literacy, specifically in imaging algorithms. In another study, basic AI literacy was evaluated, such as operational definitions. However, this study included a diverse range of literacy and understanding among healthcare professionals and students in different disciplines. Undoubtedly, with the increasing growth of studies in this field, more studies are needed to understand AI literacy, develop educational curricula, and improve the level of knowledge and literacy specifically in each educational field.

### CONCLUSION

Evidence from this systematic review shows that the majority of healthcare professionals and students were motivated to use AI to improve healthcare and welcomed AI in clinical contexts. However, few students received sufficient education and literacy in this field. We found that interest in learning the clinical applications, development, and evaluation of AI-based tools is ubiquitous, but current medical curricula do not respond to this. Students and professionals believed that learning the knowledge and skills necessary to navigate the field of AI in medicine was important and emphasized the need for multidisciplinary training on this topic. It is suggested that they provide the basic technology for the use of AI in the future. Next, they should be provided with training and resources to strengthen AI literacy and

support pioneering developments in implementing AI-based tools in healthcare systems. This near-universal desire to use AI to improve healthcare, along with concerns about training, costs, responsibilities, skill retention, data sharing, and disruption to professional practice, has to date left little work specifically on best practices for delivering literacy. AI is not focused on healthcare education. To plan more responsibly for such a complex intervention, it is crucial to consider these professional groups and their training needs in terms of technological literacy and new workflow models and empower them to participate in the leadership of change.

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## AUTHOR'S CONTRIBUTION

All authors contributed to the literature review, design, data collection and analysis, drafting the manuscript, read and approved the final manuscript.

## CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this study.

## FINANCIAL DISCLOSURE

No financial interests related to the material of this manuscript have been declared.

## ETHICS APPROVAL

This study was approved after review and presentation in the Ethics Committee of Mashhad University of Medical Sciences (Code: 4012496).



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