Artificial Intelligence in the Health Sector: Key Skills for Future Health Professionals.

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Submitted to: JMIR Medical Education
on: March 07, 2024

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Abstract

Technological advancements have significantly reshaped healthcare, introducing digital solutions that enhance diagnostics and patient care. Artificial Intelligence (AI) stands out, offering unprecedented capabilities in data analysis, diagnostic support, and personalized medicine. However, effectively integrating AI into healthcare necessitates specialized competencies among professionals, an area still in its infancy in terms of comprehensive literature and formalized training programs.

This systematic review aims to consolidate the essential skills and knowledge healthcare professionals need to integrate AI into their clinical practice effectively. Through an extensive search across PubMed, Scopus, and Web of Science, we identified literature focusing on AI fundamentals, data analytics and management, and ethical considerations. Despite the broadening of search criteria to capture the evolving nature of AI in healthcare, the review underscores a significant gap in focused studies on the required competencies. Moreover, the review highlights the critical role of regulatory bodies like the (US Food and Drug Administration) FDA in facilitating the adoption of AI technologies by establishing trust and standardizing algorithms.

Key areas were identified for developing competencies among healthcare professionals for the implementation of AI, Ai fundamentals knowledge, data analysis skills, and ethical considerations. In an AI-enhanced healthcare landscape, the ability to humanize patient care through effective communication is paramount. This balance ensures that while AI streamlines tasks and potentially increases patient interaction time, healthcare professionals maintain a focus on compassionate care, thereby leveraging AI to enhance, rather than detract from, the patient experience.

(JMIR Preprints 07/03/2024:58161)
DOI: https://doi.org/10.2196/preprints.58161

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Abstract

Technological advancements have significantly reshaped healthcare, introducing digital solutions that enhance diagnostics and patient care. Artificial Intelligence (AI) stands out, offering unprecedented capabilities in data analysis, diagnostic support, and personalized medicine. However, effectively integrating AI into healthcare necessitates specialized competencies among professionals, an area still in its infancy in terms of comprehensive literature and formalized training programs.

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Key areas were identified for developing competencies among healthcare professionals for the implementation of AI, Ai fundamentals knowledge, data analysis skills, and ethical considerations. In an AI-enhanced healthcare landscape, the ability to humanize patient care through effective communication is paramount. This balance ensures that while AI streamlines tasks and potentially increases patient interaction time, healthcare professionals maintain a focus on compassionate care, thereby leveraging AI to enhance, rather than detract from, the patient experience.

Keywords

Artificial Intelligence, Healthcare Competencies, Systematic Review, Healthcare Education, AI Regulation.

Background

The advent of Artificial Intelligence (AI) in healthcare promises to revolutionize clinical practices, offering unprecedented improvements in diagnostics, patient care, and efficiency of healthcare delivery. Despite the potential, the seamless integration of AI technologies faces significant hurdles, mainly attributed to the lack of requisite competencies among healthcare professionals. This study endeavors to systematically review existing literature to elucidate the necessary competencies for effective AI integration in healthcare settings. A thorough examination of current publications aims to delineate the present landscape and identify challenges associated with cultivating AI competencies among healthcare practitioners. The review’s objective is not only to map out the essential skills needed but also to highlight the importance of regulatory standardization and educational enhancement in overcoming the barriers to AI adoption in healthcare.

1. Introduction

Technological advancements have significantly transformed multiple sectors, notably healthcare, which has seen substantial improvements in diagnostics and patient care due to digital solutions. The application of technology in healthcare delivers multifaceted solutions, such as diagnostic support systems and telemedicine platforms, effectively reducing healthcare costs and enhancing the quality of care as perceived by both patients and professionals (1). Nonetheless, the adoption of these technologies in a safe and efficient manner encounters numerous barriers, primarily identified in scientific literature as infrastructural and related to training and education (2).

To address the challenges of technological evolution, the DigComp framework by the European Commission (3) provides crucial competencies to effectively adapt to new technologies. This framework delineates the digital competencies necessary to adapt to and capitalize on emerging technologies. A particularly vexing issue is the integration of artificial intelligence (AI) into healthcare.

AI systems utilize complex algorithms and mathematical models to analyze large data sets, identify patterns, and apply predefined rules, thereby enhancing decision-making processes in healthcare. Notably, its machine learning capabilities enable systems to autonomously gain knowledge and enhance performance over time, unfettered by hardcoded instructions (4).

AI classification is multifaceted. The European Commission differentiates between AI software, including virtual assistants and recognition systems, and AI embedded in physical devices, such as robots and autonomous vehicles (3). Alternatively, Russell and Norvig's taxonomy assesses systems based on cognitive and behavioral capabilities, distinguishing those that emulate human or rational thought and action (5).

Each AI methodology is designed to refine and adapt its functionality for specific problem-solving, whether by mimicking human behavior or optimizing decisions for logic and efficiency. This adaptability highlights AI's critical role in technological progression and its expanding utility across diverse human endeavors (4)

AI enhances clinical decision-making by overcoming human limitations in data processing, facilitating the implementation of evidence-based practices through technologies such as machine learning and deep learning (6). The clinical setting sees the application of various data science technologies, including image processing, machine learning, convolutional neural networks, and deep learning, among others (6).

Healthcare intrinsically involves significant human interaction, where empathy and active listening are paramount. Implementing AI technologies complements human interaction by mitigating cognitive biases such as unconscious reasoning, gut feelings, and heuristic shortcuts through the application of AI algorithms (7).

While human interaction remains crucial in healthcare, the precision and speed of AI algorithms offer a compelling advantage. For instance, a radiologist might review 225,000 MRI or CT scans over their career, whereas an AI-based medical image analysis algorithm can evaluate millions of images in a brief period, thereby enhancing its accuracy through continual learning (6).
The integration of AI into healthcare is more than just an advancement in technology; it represents a fundamental transformation in the operational, cultural, and ethical framework of healthcare

organizations. This transition necessitates that healthcare professionals acquire specialized knowledge in AI disciplines, including machine learning, deep learning, and natural language processing, to effectively and ethically apply AI tools in clinical settings (8).

Integrating AI into healthcare necessitates professional expertise and stringent regulatory oversight to ensure bias mitigation, data representativeness, privacy protection, and ethical technology use (9). The U.S. Food and Drug Administration (FDA) is exploring the regulation and approval of AI-based algorithms for medical application, although a distinct process for such technologies has yet to be established (10).

During this technological transition, both caution and specialized expertise are indispensable. Recent findings published in JAMA Ophthalmology (11)(12) underscore the potential risks associated with the misuse of AI tools, including those developed by sophisticated language models like ChatGPT. The study involved an artificially generated database designed to simulate a clinical trial by exhibiting statistically significant differences in specific variables.

To the untrained eye, the data might seem legitimate, yet a trained professional can discern potential falsifications by analyzing data non-randomness and variable distributions, thus identifying and raising concerns (12).

A concerted strategy to enhance AI literacy and reengineer clinical processes is critical, fostering synergy between human capabilities and AI-augmented decision-making. This approach should be grounded in a comprehensive understanding of the essential skills healthcare professionals must master, enabling them to grasp and contextualize the implications of AI on patient care processes (13) (14).

Maximizing the benefits of AI in healthcare requires professionals to undergo rigorous and specific training in technical, procedural, and collaborative skills (15). Such education will not only facilitate adaptation to a rapidly changing technological landscape but also guide the evolution towards an enhanced, forward-looking clinical practice.

This literature review aims to consolidate the requisite skills and knowledge healthcare professionals need to integrate AI into their routine clinical practice safely and effectively.

2. Methodology

In conducting a systematic review between November and December 2023, we adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (16) (see Appendix 1). Comprehensive searches were performed across databases including PubMed, Scopus, and Web of Science (WOS), employing DeCS and MeSH descriptors pertinent to artificial intelligence in healthcare and associated skills. This was complemented with boolean and truncation operators to refine the search strategy. Search queries included: ("Artificial Intelligence" OR "AI") AND "Healthcare Professionals" AND ("Skills" OR "Competencies" OR "Education"), ("Artificial Intelligence" OR "AI") AND ("data analysis" OR "ethical considerations").

("Artificial Intelligence" OR "AI") AND "Healthcare Professionals" AND ("Skills" OR "Competencies" OR "Education")		
Database	**Search**	**Results**
PubMed	All fields	126

Scopus	Article title, Abstract, Keywords	132
Web of Science (WOS)	Topic	86

Table 1. Search results

("Artificial Intelligence" OR AI) AND ("data analysis" OR "ethical considerations" OR "clinical decision-making") AND (clinicians OR physicians OR nurses)		
Database	**Search**	**Results**
PubMed	All fields	557
Scopus	Article title, Abstract, Keywords	857
Web of Science (WOS)	Topic	698

Table 2. Search results

We established specific selection criteria, prioritizing peer-reviewed original articles, review articles, editorials, and commentaries that directly explored the requisite skills for healthcare professionals to integrate AI into their practice. Regarding the inclusion criteria, studies were considered if they: were published in English or Spanish, taking advantage of the linguistic accessibility for the research team in order to reflect the possible specific characteristics of the Spanish-speaking community; had been published since 2018, ensuring the relevance and timeliness of the research in the field of AI in healthcare; focused on the necessary skills for the effective use of AI by healthcare professionals, encompassing both technical and management competencies; and included aspects related to training in digital health, highlighting the importance of specific training in the use of emerging technologies.

Conversely, studies were excluded if they: were written in languages other than English or Spanish; were published before 2018, to focus on the most recent trends in AI in healthcare; were not specifically related to the skills or needs of healthcare professionals for the use of AI tools, excluding research not directly addressing this focus; and did not refer to specific skills or training in digital health, discarding studies that did not directly contribute to understanding the competencies necessary to integrate AI into healthcare practice.

This selection methodology was designed to identify studies that provided significant evidence on the key competencies healthcare professionals need to develop for effectively integrating Ai into their clinical practice. Thus, ensuring that the systematic review focused on research offering practical and applicable insights.

An initial search utilized the aforementioned databases and descriptors (tables 1 and 2). Titles and abstracts underwent rigorous review for relevance by two independent researchers *(J.G.G.* and *C.L.S.B.*), with duplicates removed and articles not meeting inclusion criteria or fitting exclusion criteria discarded. Mendeley served as the reference management tool, not involved in the data extraction process.

Further, full-text articles were retrieved for an in-depth content review against the inclusion criteria specified in table 3. To assure methodological integrity, discrepancies were resolved through consultation with a third researcher (*J.L.S.R.*), reaching consensus on study admissibility. The screening process was manual, without the use of automation tools, and each study was carefully evaluated. Mendeley was utilized again for reference management, without affecting the data extraction process. The PRISMA flow diagram is provided in figure 1.

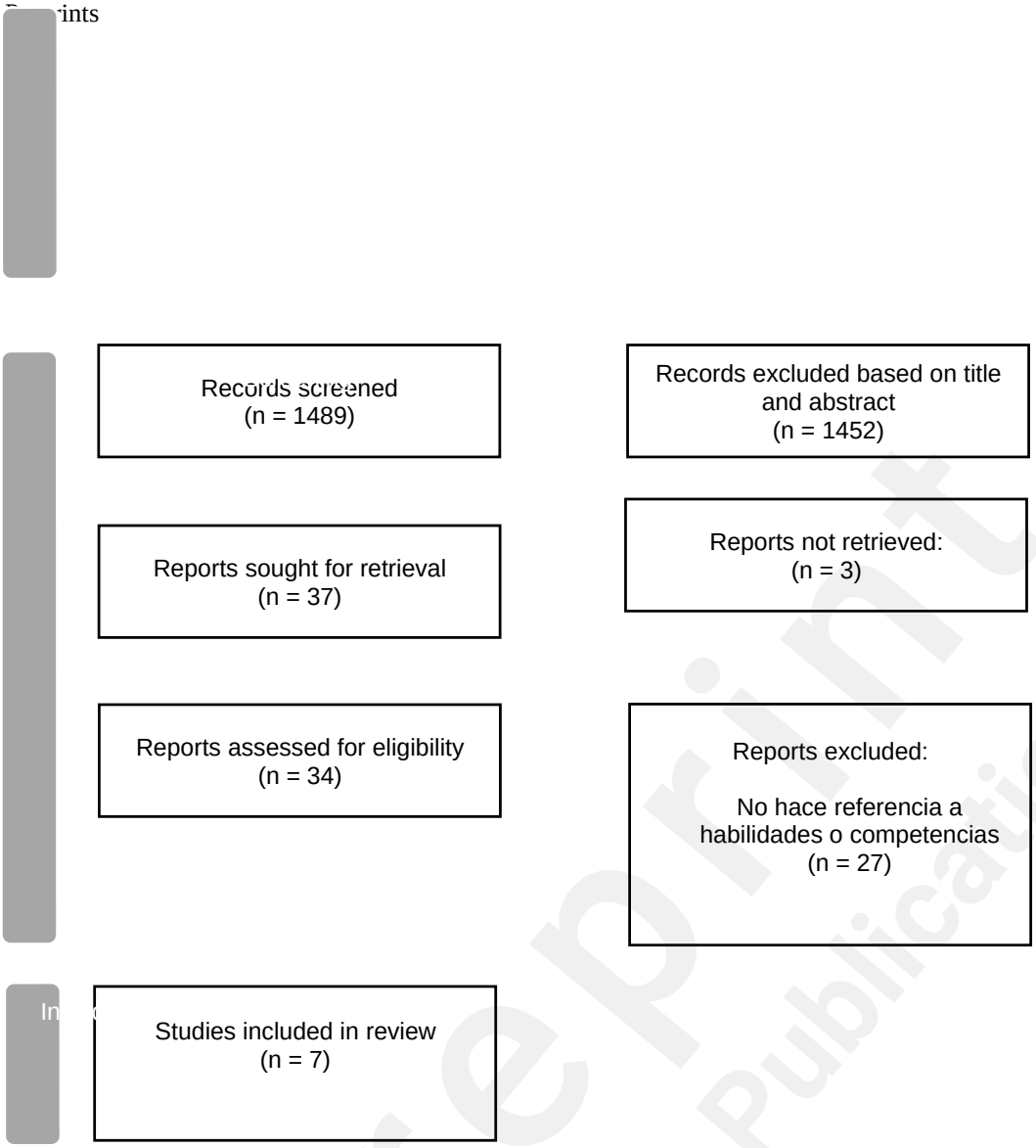

Figure 1. PRISMA Flow diagram

The GRADE framework (Grading of Recommendations Assessment, Development, and Evaluation) (17) was applied to assess the evidence quality of the included works, considering the quality of studies, result consistency, imprecision, potential bias, and other pertinent factors. Mixed-method or qualitative studies were appraised using the Mixed Methods Appraisal Tool (MMAT) (18).

Data were extracted and synthesized from eligible studies, encompassing details such as authors, publication year, study design, identified skills, and methodological quality assessment. Tables served as the primary method for tabulating and visually presenting the results and their synthesis.

Bias in the examined works was evaluated following Cochrane's domain-based recommendations (19), considering five types of bias, each with its domains. Bias risk was independently assessed by at least two reviewers, with discrepancies resolved via discussion or consultation with a third reviewer when necessary.

This review aimed to identify and delineate the skills and competencies essential for healthcare professionals to employ artificial intelligence in their clinical practices effectively. The objective encompassed various outcome domains, not limited to interpreting results from machine learning models, managing AI biases, ethical considerations in AI-assisted decision-making, and the technical skills required for effective AI tool utilization.

The data search spanned all pertinent dimensions of these outcomes, including variables relevant to the analyzed studies. These variables covered aspects such as humanization, social skills, and participants' AI usage experience, offering a comprehensive perspective on the competencies necessary for integrating AI into healthcare practices.

3. Results

In the initial phase of study selection, grounded in pre-defined inclusion and exclusion criteria, A significant portion of the identified literature did not meet the rigorous methodological standards required for inclusion, specifically Level I to IIa evidence according to the Oxford Centre for Evidence-Based Medicine or comprehensive meta-analyses. This phenomenon can largely be attributed to the nascent and swiftly evolving domain of artificial intelligence (AI) in healthcare, resulting in a research corpus that is varied and less uniform in study design.

In recognition of the dynamic and rapidly evolving nature of the field, we broadened our inclusion criteria to encompass systematic reviews, qualitative studies, and other research methodologies. This strategic decision acknowledges that these forms of research, although not strictly meeting the initially mandated levels of evidence, are indispensable for providing deep insights into the competencies healthcare professionals need to effectively implement and utilize AI in clinical settings. By expanding our criteria, we aimed to capture a more comprehensive and nuanced view of the existing body of knowledge on AI in healthcare. This approach ensures that our systematic review accurately reflects the spectrum of current trends, challenges, and opportunities for skill development, thereby offering a holistic understanding of the competencies essential for integrating AI into healthcare practices

Database searches yielded 2,457 articles. Following title and abstract screening, 37 articles were selected for full-text review, from which only 7 met all inclusion criteria for this systematic review (20) (21) (22) (23) (24) (25) (26). Each selected article specifically concentrated on the competencies essential for the integration of AI into routine clinical practice. A substantial number of the excluded articles (n=28) made reference to, but did not directly engage with, the competencies in question. Table 3 delineates the characteristics of these studies and the principal competencies identified therein.

One notable inclusion is a 2022 Delphi study: "*What competencies are required by medical graduates to be prepared for AI technologies in medicine, and what consensus levels do expert panels hold regarding these competencies?*", (20), which aimed to identify the competencies medical graduates require to effectively use AI technologies in medicine. This study achieved a strong consensus on 23 competencies, highlighting the importance of understanding AI fundamentals, ethics, data management, and analysis, as well as integrating AI into medical practice.

Additionally, a systematic review (26)proposed a competency framework for AI in healthcare, categorizing essential skills across three distinct groups: medical students, medical informatics specialists, and computer scientists. This framework suggests a focused approach to developing AI-related competencies, emphasizing the need for healthcare professionals to master clinical applications of AI algorithms and evaluate AI technology biases

Table 3 catalogs the competencies deemed indispensable by the analyzed articles, with all contributions (20) - (26) underscoring the critical acquisition of skills predominantly in three domains: AI fundamentals, data analysis and management, and ethical considerations.

Some investigations highlight more technical abilities, such as programming (23), or a deeper mathematical acumen (21) (25). Conversely, a capability deemed highly significant across the literature is the aptitude for evaluating AI tools to ascertain their quality, biases, and rationalize their application, in addition to scrutinizing potential biases and limitations (21) (22).

The literature review underscores the dual importance of technical and communication skills. While technical proficiency in programming and data analysis is crucial, the ability to communicate effectively and humanize patient care in the context of AI use is equally vital for healthcare professionals. The advent of AI is poised to afford providers increased patient interaction time by streamlining certain tasks. Moreover, professionals must endeavor to humanize care, ensuring patients feel cared for, even in the context of AI assistance, thereby justifying its application and safeguarding confidentiality (22).

A 2022 exploratory review (27) highlighted a significant gap in the literature concerning the definition of explicit clinical competencies for AI in healthcare. This finding underscores the urgent need for further research to define and standardize AI competencies in clinical settings. This revelation reinforces our observations and highlights a significant research and professional competency development gap in this area.

The potential biases were scrutinized and expounded upon in table 4. Given the nature of the selected articles, a conventional methodological quality analysis using the GRADE or MMAT frameworks was not feasible. These tools are designed for experimental or quasi-experimental studies, which contrasts with the qualitative and review-based nature of the included research.

Title	Authors	Study Type	Identified Potential Biases
***Artificial intelligence in medical education curriculum: An e-Delphi study for competencies*(20)**	Çalışkan SA, Demir K, Karaca O.	Delphi	Performance Bias
***Current challenges and barriers to real-world artificial intelligence adoption for the healthcare system, provider, and the patient.*(21)**	Singh RP, Hom GL, Abramoff MD, Campbell JP, Chiang MF, on behalf of the AAO Task Force on Artificial Intelligence	Perspective Analysis	Selection Bias Performance Bias Detection Bias
***Competencies for the use of artificial intelligence in primary care* (22)**	Liaw W, Kueper JK, Lin S, Bazemore A, Kakadiaris I.	Theoretical review	Reporting Bias
***What do medical students actually need to know about artificial intelligence?*(23)**	McCoy LG, Nagaraj S, Morgado F, Harish V, Das S, Celi LA.	Conceptual Review / Commentary	Performance Bias Reporting Bias
***Stakeholder perceptions of the safety and assurance of artificial intelligence in healthcare*(24)**	Sujan, Mark A.; White, Sean; Habli, Ibrahim; Reynolds, Nick	Semi-structured Interview	Reporting Bias Detection Bias

***Developing an Artificial Intelligence–Enabled Health Care Practice: Rewiring Health Care Professions for Better Care*(25)**	David Wiljer, Zaki Hakim,	Commentary	Detection Bias Reporting Bias Performance Bias
***Artificial Intelligence Education and Tools for Medical and Health Informatics Students: Systematic Review*(26)**	Sapci A, Sapci H	Systematic Review	-

Table 4. Assessment of Potential Biases

4. Discussion

Across the reviewed literature, there is a unanimous recognition of the urgent need to integrate Artificial Intelligence (AI) competencies into the training of healthcare professionals. A survey among nursing staff in 2022 (28) revealed that the majority had acquired their AI skills on their own, and 75% of the respondents believed AI should be included in academic curricula, indicating its expected significant role in various clinical applications.

This systematic review highlights the critical importance of incorporating training that addresses foundational competencies, specifically data science basics, data analysis and management, and ethical considerations, as identified in studies (20) - (26). Among these, data analysis and management are emphasized as particularly crucial. This is due to healthcare professionals often being the primary data generators, necessitating skills in managing and interpreting large datasets to effectively apply AI methodologies in clinical practice (29).

A publication in 2021 (30) stressed the importance of high-quality data and the risks associated with its mismanagement, thus underscoring the legal and ethical implications. An essential skill set includes the ability to evaluate the quality of algorithms and their interpretations, with an acute awareness of potential biases, requiring a deep understanding of AI principles. Some studies (31) have offered guides to help clinicians assess these aspects without needing in-depth expertise in computational algorithms or linear algebra.

Drawing an analogy, clinicians utilizing ultrasound technology are not expected to fully understand the physics of sound waves or the technical details of imaging devices. However, they are required to be able to accurately interpret and evaluate the images. Similarly, the goal for AI education should focus on developing skills for interpreting AI outputs and explaining these findings to patients (32).

Despite widespread agreement on the necessity for comprehensive AI training from the outset of medical education, there is a lack of consensus on the specific content and approach of such training (15). The discussion around this issue is abundant, yet concrete resolutions are rare.

Several authors argue that the existing academic infrastructure is ill-equipped to incorporate AI education, citing time constraints and a lack of teaching expertise as significant obstacles. An alternative proposed involves the use of specific AI tools not only for clinical applications but also to elucidate the underlying algorithms, focusing on their practical use and ethical implications (33).

A solution for integrating AI education into healthcare curricula, addressing the shortage of instructors with expertise in clinical AI applications, involves leveraging established training programs from other institutions (34). Programs by Stanford University (35) and Harvard University

(36) serve as examples, providing access to high-quality educational content.

The opacity of machine learning algorithms, often referred to as "black boxes" due to their complex and abstract problem-solving methods, represents a notable challenge to the medical application of AI solutions (37). While efforts to objectively assess these algorithms are still emerging (38), the primary focus for healthcare professionals remains the use of tools that deliver precise and trustworthy responses. The importance of regulatory frameworks, such as the one provided by the U.S. Food and Drug Administration (FDA), which has approved AI tools for specific clinical applications (39), is paramount in building trust among clinicians and patients alike.

Regulated, FDA-approved tools alleviate liability concerns for healthcare providers, enhancing their confidence and facilitating wider adoption of AI technologies.

The integration of AI into clinical practice is expected to augment, not replace, the roles of healthcare professionals. It calls for a workforce proficient in digital health and communication, capable of leveraging AI's benefits while recognizing its limitations and ethical considerations (40). This paradigm shift offers an opportunity to enhance patient care, delegating computational tasks to AI and focusing on the human aspects of healthcare delivery (37).

5. Conclusions

Recent data from Rockhealth, a venture capital firm specializing in digital health, have underscored an exponential increase in investments directed towards digital health enterprises and related technologies (41). This trend distinctly signals an evolving healthcare landscape, increasingly reliant on novel technologies, thereby accentuating the imperative for healthcare professionals to proficiently integrate such advancements into their clinical practices (42).

This systematic review endeavors to delineate the competencies requisite for healthcare professionals to effectively integrate Artificial Intelligence (AI) into their clinical operations. Despite the nascent and somewhat superficial exploration within the current literature on this topic, it has been feasible to identify three critical domains: AI fundamentals, data analytics and management, and ethical considerations (20) - (26). A consensus within the scholarly discourse suggests the necessity for healthcare professionals to attain proficiency in these domains to ensure the judicious application of AI tools, thereby accruing benefits for both patients and the healthcare ecosystem.

The ambition extends beyond merely acquiring proficiency in disciplines ancillary to traditional healthcare paradigms. Considering the already intricate and comprehensive nature of healthcare education, particularly in medicine, the emphasis is placed on fostering an in-depth comprehension of AI's functionalities, inherent biases, its pragmatic utility, and cost-effectiveness vis-à-vis the abstention from AI applications.

Regulatory standardization of algorithms, as undertaken by authorities like the FDA (9), is intended to surmount one of the principal obstacles in digital tool adoption: the inertia against change prevalent among healthcare practitioners (2). Such regulatory frameworks not only enhance professional trust in these digital tools but also transfer a significant portion of the accountability to these regulatory institutions.

Augmenting the education and training of healthcare professionals is posited to elevate their confidence in utilizing these tools. Although concerns persist regarding AI's potential to supplant human roles, a more discerning view proposes that AI will primarily alleviate the burden of mundane

tasks. This reallocation of time and resources is anticipated to enhance patient interactions and elevate the quality of healthcare services provided (39).

In this context, the importance of communication skills becomes increasingly paramount. The introduction of AI tools is expected to afford healthcare professionals additional time per patient encounter, potentially heightening patient satisfaction and care quality.

The integration of AI into healthcare is indispensable for advancing patient care but requires a concerted effort to develop and standardize competencies among healthcare professionals. Regulatory oversight and enhanced educational frameworks are essential for overcoming existing barriers and leveraging AI's full potential in clinical settings.

The academic consensus underscores the criticality of bespoke AI training for healthcare professionals to facilitate the seamless integration of AI into clinical practice. However, a definitive consensus on the precise contours of such training is yet to be achieved (34). This review has shed light on areas of consensus, underscoring the exigency for further research to explicitly define these domains and establish the knowledge benchmarks clinicians must exceed to incorporate these competencies effectively into their educational curricula.

6. Limitations

This systematic review confronts the inherent challenge posed by the limited availability of literature specifically addressing the competencies required for integrating Artificial Intelligence (AI) into healthcare practice. This paucity is likely due to the nascent state and rapid development of AI applications in healthcare, leading to a dearth of studies that meticulously dissect the requisite skills for healthcare professionals to effectively leverage AI technologies.

To counteract the scarcity of targeted literature, the search criteria were broadened to encompass more general terms related to AI in healthcare and healthcare professionals' competencies. This broadening, while necessary, may have introduced studies into the review that, despite their relevance, do not exclusively concentrate on the competencies for AI utilization. Consequently, this approach may have injected variability into the findings and detracted from the homogeneity of the sample analyzed.

Additionally, the review faced potential language bias, given the primary focus on literature available in English and Spanish. Despite a comprehensive search in these languages, pertinent studies published in other languages might have been inadvertently excluded. It is important to recognize that the study selection process, despite being rigorous and involving independent reviews by two researchers, could still be influenced by subjective interpretation of the inclusion and exclusion criteria.

Limiting the review to studies published after 2018 aimed to capture the most recent advancements in the field. Nonetheless, this temporal restriction might omit emerging research published subsequent to the review's commencement. Despite these challenges, meticulous selection and assessment protocols were employed to ensure the credibility and relevance of the review's findings.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

All data generated or analyzed during this study are included in this published article. This encompasses detailed descriptions of the databases consulted, the search criteria employed, the selection process for the included studies, and the analytical methods applied. Specifically, the manuscript delineates the comprehensive search strategy, including the exact search terms, the databases accessed (PubMed, Scopus, Web of Science), and the filters used (such as publication date ranges and language restrictions). Additionally, the criteria for study selection—both inclusion and exclusion criteria—are explicitly outlined to ensure reproducibility and transparency of the review process. The methodologies utilized for data extraction and analysis are also described, providing insight into how the findings were synthesized and interpreted. Through this approach, we aim to ensure that our systematic review process is fully transparent, enabling other researchers to replicate the study or to conduct further analysis based on the procedures and data sets detailed within this article

Competing interests

The authors declare that they have no competing interests

Funding

This work has been partially supported by the Telefonica Chair on “Intelligence in Networks” of the Universidad de Sevilla.

Authors' contributions

All authors contributed significantly to this literature review. Specifically, each author participated in one or more of the following: conceptualization and design of the review, data acquisition, analysis, interpretation, or critically revising the work. All authors approved the final manuscript for publication and agree to be accountable for all aspects of the work, ensuring the integrity and accuracy of their contributions.

Acknowledgements

Not applicable

Appendix 1: Tables

Title	Authors	Type of Study	Identified Skills
***Artificial intelligence in medical education curriculum: An e-Delphi study for competencies*(20)**	Çalışkan SA, Demir K, Karaca O.	Delphi	Use of health data according to legal and ethical standards. Acting according to ethical principles when using AI technologies. Appropriate use of AI applications. Maintenance of health records for AI processing. Use of information from AI applications along with professional knowledge. Assessment of AI use for educational, service, and research purposes. Explanation of how AI applications in health offer solutions to specific problems. Organization of workflow in accordance with AI work logic. Effective and efficient use of AI technologies in health service delivery. Definition of basic data science concepts. Keeping up with current developments and literature on the use of AI technologies in health. Teamwork with experts in the development of AI applications. Accessing, evaluating, using, sharing, and creating new information through information and communication technologies. Following legal regulations regarding the use of AI technologies in health. Expressing the importance of data collection, analysis, evaluation, and security for the development of AI applications in health. Anticipating opportunities and threats that AI technology may create. Differentiating between functions and features of AI-related tools and applications. Proper analysis of data obtained by AI in health. Definition of basic concepts and terminology of AI. Definition of basic statistical concepts. Decision-making regarding the use of AI technologies in health. Explanation of how doctors' knowledge and experiences can be used in developing AI applications. Choosing the appropriate AI application for health problems.
Current challenges and barriers to real-world artificial intelligence adoption for the	Singh RP, Hom GL, Abramoff MD, Campbell JP, Chiang MF, on behalf	Análisis de perspectivas	AI fundamentals. Mathematical concepts. Data analysis and management.

***healthcare system, provider, and the patient.*(21)**	of the AAO Task Force on Artificial Intelligence		Training on AI Biases and Limitations. Ethical and Legal Issues.
***Competencies for the use of artificial intelligence in primary care* (22)**	Liaw W, Kueper JK, Lin S, Bazemore A, Kakadiaris I.	Revisión Teórica	AI fundamentals. Legal regulations of AI tools. Evidence evaluation of tools. Skills in tool use and data capture. Technical Use: Technical skills needed to efficiently operate AI-based tools. Communicating with patients to inform about AI use.
***What do medical students actually need to know about artificial intelligence?*(23)**	McCoy LG, Nagaraj S, Morgado F, Harish V, Das S, Celi LA.	Revisión conceptual / Comentario	Understanding of AI applications in Health. Skills in Data analysis, acquisition, cleaning, and visualization Programming skills. Critical evaluation of AI. Conceptual understanding of AI and Clinical Data Science. Ethical Considerations in AI. Dual training in medicine and Informatics/Data Science.
***Stakeholder perceptions of the safety and assurance of artificial intelligence in healthcare*(24)**	Sujan, Mark A.; White, Sean; Habli, Ibrahim; Reynolds, Nick	Entrevista semiestructurada	AI fundamentals. Monitoring and supervision of AI systems. Understanding and conveying information generated by AI. Promoting trust in AI. Maintaining essential clinical skills despite automation.
***Developing an Artificial Intelligence–Enabled Health Care Practice: Rewiring Health Care Professions for Better Care*(25)**	David Wiljer, Zaki Hakim,	Comentario	Data governance principles. Basic statistics and algorithmic decision-making. Data visualization capabilities and storytelling. Understanding how business or clinical processes will be altered by integrating artificial intelligence technologies into healthcare.
***Artificial Intelligence Education and Tools for Medical and Health Informatics Students: Systematic Review*(26)**	Sapci A, Sapci H	Revisión sistemática	AI predictive techniques. AI ethics. Evaluation of AI tools.

Table 3. Studies Included in the Review

Appendix 2: PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	4-6
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	6
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	7
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	7
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	7
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	7-8
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	7-8
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	8
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	8
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	10
Effect	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	NA

Section and Topic	Item #	Checklist item	Location where item is reported
measures			
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	7-8
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	7-8
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	8
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	NA
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	NA
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	NA
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	10
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	9-10
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	10
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	10
Study characteristics	17	Cite each included study and present its characteristics.	23-24
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	14
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	-
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	-
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	-
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	-

Section and Topic	Item #	Checklist item	Location where item is reported
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	-
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	15
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	14
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	14-16
	23b	Discuss any limitations of the evidence included in the review.	19
	23c	Discuss any limitations of the review processes used.	19
	23d	Discuss implications of the results for practice, policy, and future research.	18
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	10
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	10
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	10
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	21
Competing interests	26	Declare any competing interests of review authors.	22
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	-

References

1. Borges do Nascimento IJ, Abdulazeem HM, Vasanthan LT, Martinez EZ, Zucoloto ML, Østengaard L, et al. The global effect of digital health technologies on health workers' competencies and health workplace: an umbrella review of systematic reviews and lexical-based and sentence-based meta-analysis. Lancet Digit Health. 2023 Aug;5(8):e534–44.
2. Borges do Nascimento IJ, Abdulazeem H, Vasanthan LT, Martinez EZ, Zucoloto ML, Østengaard L, et al. Barriers and facilitators to utilizing digital health technologies by healthcare professionals. NPJ Digit Med. 2023 Sep 18;6(1):161.
3. Commission E, Centre JR, Vuorikari R, Kluzer S, Punie Y. DigComp 2.2, The Digital Competence framework for citizens – With new examples of knowledge, skills and attitudes. Publications Office of the European Union; 2022.
4. Gobierno de España. Qué es la Inteligencia Artificial [Internet]. 2023 [cited 2024 Mar 3]. Available from: https://planderecuperacion.gob.es/noticias/que-es-inteligencia-artificial-ia-prtr
5. Stuart Russell, Peter Norvig. Artificial Intelligence: A Modern Approach, 4th Global ed. 4th ed. Pearson; 2022.
6. Mintz Y, Brodie R. Introduction to artificial intelligence in medicine. Minimally Invasive Therapy & Allied Technologies. 2019 Mar 4;28(2):73–81.
7. Liu X, Zhang W, Zhang Q, Chen L, Zeng T, Zhang J, et al. Development and validation of a machine learning-augmented algorithm for diabetes screening in community and primary care settings: A population-based study. Front Endocrinol (Lausanne). 2022 Nov 28;13.
8. Kim HS, Kim DJ, Yoon KH. Medical Big Data Is Not Yet Available: Why We Need Realism Rather than Exaggeration. Endocrinology and Metabolism. 2019;34(4):349.
9. González Arencibia M, Martínez Cardero D. Dilemas éticos en el escenario de la inteligencia artificial. Economía y Sociedad. 2020 May 12;25(57):1–18.
10. Harvey HB, Gowda V. How the FDA Regulates AI. Acad Radiol. 2020 Jan;27(1):58–61.
11. Taloni A, Scorcia V, Giannaccare G. Large Language Model Advanced Data Analysis Abuse to Create a Fake Data Set in Medical Research. JAMA Ophthalmol. 2023 Nov 9;
12. Naddaf M. ChatGPT generates fake data set to support scientific hypothesis. Nature. 2023 Nov 30;623(7989):895–6.
13. Lauricella LL, Pêgo-Fernandes PM. Databases, big data and artificial intelligence: what healthcare professionals need to know about them. Sao Paulo Medical Journal [Internet]. 2022 Dec;140(6):737–8. Available from: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-31802022000600737&tlng=en
14. Kamble SS, Gunasekaran A, Goswami M, Manda J. A systematic perspective on the applications of big data analytics in healthcare management. Int J Healthc Manag. 2019 Jul 3;12(3):226–40.
15. Grunhut J, Wyatt AT, Marques O. Educating Future Physicians in Artificial Intelligence (AI): An Integrative Review and Proposed Changes. J Med Educ Curric Dev [Internet]. 2021 Jan 6;8:238212052110368. Available from: http://journals.sagepub.com/doi/10.1177/23821205211036836
16. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med. 2009 Jul 21;6(7):e1000097.
17. Aguayo-Albasini JL, Flores-Pastor B, Soria-Aledo V. Sistema GRADE: clasificación de la calidad de la evidencia y graduación de la fuerza de la recomendación. Cir Esp. 2014 Feb;92(2):82–8.

18. Hong QN, Fàbregues S, Bartlett G, Boardman F, Cargo M, Dagenais P, et al. MIXED METHODS APPRAISAL TOOL (MMAT) VERSION 2018. Vol. 34. Canada: Education for Information; 2018. 285–291 p.
19. Centro Cochrane Iberoamericano traductores. Manual Cochrane de Revisiones Sistemáticas de Intervenciones, versión 5.1.0 . Barcelona: Centro Cochrane Iberoamericano; 2012.
20. Çalışkan SA, Demir K, Karaca O. Artificial intelligence in medical education curriculum: An e-Delphi study for competencies. PLoS One. 2022 Jul 21;17(7):e0271872.
21. Singh RP, Hom GL, Abramoff MD, Campbell JP, Chiang MF. Current Challenges and Barriers to Real-World Artificial Intelligence Adoption for the Healthcare System, Provider, and the Patient. Transl Vis Sci Technol. 2020 Aug 11;9(2):45.
22. Liaw W, Kueper JK, Lin S, Bazemore A, Kakadiaris I. Competencies for the Use of Artificial Intelligence in Primary Care. The Annals of Family Medicine. 2022 Nov;20(6):559–63.
23. McCoy LG, Nagaraj S, Morgado F, Harish V, Das S, Celi LA. What do medical students actually need to know about artificial intelligence? NPJ Digit Med. 2020 Jun 19;3(1):86.
24. Sujan MA, White S, Habli I, Reynolds N. Stakeholder perceptions of the safety and assurance of artificial intelligence in healthcare. Saf Sci. 2022 Nov;155:105870.
25. Wiljer D, Hakim Z. Developing an Artificial Intelligence–Enabled Health Care Practice: Rewiring Health Care Professions for Better Care. J Med Imaging Radiat Sci. 2019 Dec;50(4):S8–14.
26. Sapci AH, Sapci HA. Artificial Intelligence Education and Tools for Medical and Health Informatics Students: Systematic Review. JMIR Med Educ. 2020 Jun 30;6(1):e19285.
27. Garvey K V, Thomas Craig KJ, Russell R, Novak LL, Moore D, Miller BM. Considering Clinician Competencies for the Implementation of Artificial Intelligence–Based Tools in Health Care: Findings From a Scoping Review. JMIR Med Inform. 2022 Nov 16;10(11):e37478.
28. Abuzaid MM, Elshami W, Fadden SM. Integration of artificial intelligence into nursing practice. Health Technol (Berl). 2022 Nov 14;12(6):1109–15.
29. Khanra S, Dhir A, Islam AKMN, Mäntymäki M. Big data analytics in healthcare: a systematic literature review. Enterp Inf Syst. 2020 Aug 8;14(7):878–912.
30. Stöger K, Schneeberger D, Kieseberg P, Holzinger A. Legal aspects of data cleansing in medical AI. Computer Law & Security Review. 2021 Sep;42:105587.
31. Faes L, Liu X, Wagner SK, Fu DJ, Balaskas K, Sim DA, et al. A Clinician's Guide to Artificial Intelligence: How to Critically Appraise Machine Learning Studies. Transl Vis Sci Technol. 2020 Feb 12;9(2):7.
32. Nagy M, Radakovich N, Nazha A. Why Machine Learning Should Be Taught in Medical Schools. Med Sci Educ. 2022 Apr 24;32(2):529–32.
33. Chan KS, Zary N. Applications and Challenges of Implementing Artificial Intelligence in Medical Education: Integrative Review. JMIR Med Educ. 2019 Jun 15;5(1):e13930.
34. Grunhut J, Marques O, Wyatt ATM. Needs, Challenges, and Applications of Artificial Intelligence in Medical Education Curriculum. JMIR Med Educ. 2022 Jun 7;8(2):e35587.
35. Stanford University. https://online.stanford.edu/explore?type=All&topics%5B1052%5D=1052&topics%5B1060%5D=1060&topics%5B1067%5D=1067&filter%5B0%5D=topic%3A1052&filter%5B1%5D=topic%3A1060&filter%5B2%5D=topic%3A1067&filter%5B3%5D=topic%3A1098. Stanford Online.
36. Harvard University. https://aihap.mgh.harvard.edu/program-info/. Artificial Intelligence

in Healthcare Accelerated Program.
37. Lysaght T, Lim HY, Xafis V, Ngiam KY. AI-Assisted Decision-making in Healthcare. Asian Bioeth Rev. 2019 Sep 12;11(3):299–314.
38. Savage N. Breaking into the black box of artificial intelligence. Nature. 2022 Mar 29;
39. Milam ME, Koo CW. The current status and future of FDA-approved artificial intelligence tools in chest radiology in the United States. Clin Radiol. 2023 Feb;78(2):115–22.
40. Heckman GA, Hirdes JP, McKelvie RS. The Role of Physicians in the Era of Big Data. Canadian Journal of Cardiology. 2020 Jan;36(1):19–21.
41. Zweig MDJ from:, WHCTDCEEBGIGDHCPPR. Rock Health. 2021. Q1 2021 funding report: Digital health is all grown up.
42. Marwaha JS, Landman AB, Brat GA, Dunn T, Gordon WJ. Deploying digital health tools within large, complex health systems: key considerations for adoption and implementation. NPJ Digit Med. 2022 Jan 27;5(1):13.