

RESEARCH

Open Access



Trends analysis and future study of medical and pharmacy education: a scoping review

Manuchehr Bashirynejad¹ , Fatemeh Soleymani^{1*}, Shekoufeh Nikfar¹, Ali Zackery², Abbas Kebriaeezadeh¹, Reza Majdzadeh³, Behzad Fatemi¹ and Nafiseh Zare⁴

Abstract

Background This scoping review aims to provide a comprehensive analysis of emerging trends and future developments in medical and pharmacy education, addressing the need to adapt educational approaches to the rapidly evolving healthcare landscape.

Methods A systematic literature search was conducted in multiple databases to identify relevant studies published between April 2014 and April 2024. Studies pertaining to trends, forecasting, and future directions in medical and pharmacy education were included. Data extraction and synthesis followed a comprehensive process involving independent reviewers and standardized forms. Emerging themes were identified through coding and conceptual mapping techniques.

Results Out of the 926 records found, a total of 22 studies were reviewed, revealing several key trends: (1) Integration of artificial intelligence (AI), virtual/augmented reality (VR/AR), and digital technologies to enhance learning and skills; (2) Curricular reforms emphasizing interprofessional education, value-based care, population health, and social determinants; (3) Adoption of multidisciplinary approaches incorporating genomics, biotechnology, and data science; (4) Increased focus on preventive care and chronic disease management; (5) Establishment of ethical frameworks and competency standards for human-AI collaboration. A significant emphasis was placed on balancing technological innovation with core clinical skills and humanistic values.

Conclusions This review highlights transformative trends in medical and pharmacy education, providing insights for stakeholders on aligning curricula and teaching methods with the evolving healthcare landscape. Embracing technological advancements like AI and VR/AR, while promoting adaptability, interdisciplinary collaboration, and patient-centered care, is essential for maintaining educational relevance. Developing a workforce proficient in human-AI collaboration and equipped with multidisciplinary expertise is crucial for future healthcare delivery.

Keywords Medical education, Pharmacy education, Future trends, Foresight, Forecasting

*Correspondence:

Fatemeh Soleymani
fsolemani@yahoo.com

¹Department of Pharmacoeconomics and Pharmaceutical Management, Tehran University of Medical Sciences, Tehran, Iran

²Department of Industrial Engineering and Futures Studies, Faculty of Engineering, University of Isfahan, Isfahan, Iran

³Global Public Health, School of Health and Social Care, University of Essex, Colchester, England

⁴Faculty of Pharmacy, Islamic Azad University Ayatollah Amoli, Amol, Iran



© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

Background

Medical and pharmacy education play pivotal roles in shaping the future healthcare workforce and directly influencing patient care and public health outcomes [1]. As the landscape of healthcare continues to evolve, driven by technological advancements, demographic shifts, and changing disease patterns, the field of medical and pharmacy education faces significant challenges and opportunities [2, 3]. Navigating these changes necessitates a critical examination of current trends and a forward-looking analysis to anticipate future developments [4].

The medical education sector has a long-standing tradition of adapting to meet society's evolving healthcare needs [5]. From the earliest forms of apprenticeship models to the modern era of interdisciplinary, competency-based curricula, this field has continuously transformed to equip future practitioners with the knowledge, skills, and competencies required to deliver high-quality care [6]. However, the rapid pace of change in healthcare poses ongoing challenges for medical and pharmacy education programs to keep pace with emerging trends and prepare graduates for the dynamic healthcare environment they will encounter [7, 8].

In recent years, the integration of digital technologies, such as virtual and augmented reality simulations, online learning platforms, and data analytics, has revolutionized the way medical and pharmacy education is delivered [9–11]. These technological advancements offer opportunities to enhance learning experiences, facilitate skill development, and promote interprofessional collaboration [12]. Additionally, the growing emphasis on interprofessional education and team-based care models has necessitated a shift towards more collaborative and interdisciplinary approaches in medical and pharmacy curricula [13, 14].

Moreover, the medical education sector must evolve to address shifting population demographics, emerging health challenges, and the increasing prevalence of chronic diseases. Incorporating principles of preventive care, geriatrics, and chronic disease management into curricula is crucial for preparing future healthcare professionals to meet the needs of an aging population and address the rising burden of non-communicable diseases [15–19].

Furthermore, the regulatory landscape surrounding medical and pharmacy education is constantly evolving, with changes in accreditation standards, licensure requirements, and practice scope impacting the design and delivery of educational programs [20]. Navigating these regulatory shifts while maintaining educational quality and fostering innovation presents ongoing challenges for institutions and regulatory bodies alike [21].

In light of these emerging trends and challenges, a comprehensive analysis of the future trajectory of medical and pharmacy education is warranted. By examining technological advancements, pedagogical innovations, demographic shifts, regulatory changes, and other influential factors, this scoping review aims to provide a holistic understanding of the potential transformations on the horizon. The insights gained from this study will empower medical and pharmacy education stakeholders to proactively adapt their programs, curricula, and approaches, ensuring that future healthcare professionals are equipped with the knowledge, skills, and competencies necessary to deliver high-quality, patient-centered care in an ever-changing healthcare landscape. Ultimately, this forward-looking analysis seeks to contribute to the continuous improvement of medical and pharmacy education, thereby enhancing patient outcomes and advancing the overall healthcare system. This scoping review specifically aims to map and analyze emerging future trends—technological, curricular, social, and policy-related—in medical and pharmacy education. By doing so, it seeks to offer actionable insights for curriculum developers and education policymakers preparing for the next decade of health professions education."

Methods

Protocol

This scoping review meticulously follows the methodological framework outlined by the Joanna Briggs Institute (JBI) for conducting scoping reviews [22]. This framework was selected due to its recognized rigor and comprehensive approach, ensuring transparency throughout the review process.

Eligibility criteria

Out of the 926 records retrieved from database searches, 22 studies met the inclusion criteria and were included in the final analysis. The majority of the records were excluded during the screening process due to lack of relevance, incomplete information, or failure to meet the defined inclusion criteria.

Inclusion criteria

The inclusion criteria were designed to capture relevant studies that provide insights into this topic. Eligible studies must have been published between April 2014 and April 2024, allowing for the examination of recent and emerging trends. The focus was on studies pertaining to medical education (undergraduate, graduate, and continuing education), pharmacy education (entry-level, post-graduate, and continuing education), and interprofessional education involving medical and pharmacy students or professionals. Topics of interest included technological innovations in education delivery

(e.g., virtual reality, online learning), curricular reforms and pedagogical advancements, integration of emerging healthcare trends (e.g., precision medicine, digital health), interprofessional collaboration and team-based learning, and the impact of changing demographics and disease burden. The primary review question guiding this scoping review was: 'What are the emerging trends and future directions in medical and pharmacy education that should inform curriculum development and policy?' Based on this question, inclusion and exclusion criteria were designed to identify relevant literature addressing future-oriented changes in medical and pharmacy education.

Exclusion criteria

To maintain the scope of the review and ensure the relevance of the included studies, several exclusion criteria were applied. Studies that solely focused on other healthcare professions without considering medical or pharmacy education were excluded. Additionally, studies investigating educational interventions or curricula specific to medical or pharmacy subspecialties, without broader implications for overall education trends, were not included. Studies with a primary emphasis on continuing education or professional development for practicing healthcare professionals, without explicit relevance to formal medical or pharmacy education programs, were also excluded. Finally, conference abstracts, editorials, commentaries, or opinion pieces lacking original research data or policy analysis were not considered eligible for inclusion in this review.

By adhering to these carefully defined inclusion and exclusion criteria, this scoping review aims to synthesize the most relevant and informative literature on trends and future directions in medical and pharmacy education. This approach ensures that the findings of the review provide valuable insights and recommendations for enhancing and adapting medical and pharmacy education programs to meet the evolving needs of the healthcare landscape.

Information sources and search strategy

An electronic literature search was performed on April 11, 2024, using multiple databases, including PubMed, Scopus, and Web of Science. Various combinations of keywords were employed in the search process, such as "future", "forecast", "foresight", "Pharma", "Medical", and "education". The results of the electronic search can be found in Supplementary Material 1. Although Medline was not searched directly, we used PubMed, which includes most of Medline's indexed content. Future updates of this review could include direct Medline searches to enhance comprehensiveness.

Study selection process

All the records obtained from the electronic search were exported to Mendeley Desktop to identify eligible papers. Duplicate articles were removed, and the titles and abstracts of the remaining Studies were independently screened by two team members (MB and BF) based on the predetermined inclusion and exclusion criteria. After assessing the relevance of the Studies, the full texts of the potentially eligible publications were retrieved for a thorough review and assessment. This process ensured a rigorous evaluation of the Studies to determine their suitability for inclusion in the study. Articles were excluded based on several factors, including lack of relevance to future trends, absence of original data or policy insights, or focus solely on non-target disciplines (e.g., dentistry, nursing).

Data items and data abstraction

The data abstraction process was carried out by two independent reviewers (NZ and FS) using a standardized data abstraction form specifically designed to capture relevant information from the included studies. The extracted data covered various aspects, including study characteristics, research objectives, methodologies employed, and key findings related to trends and forecasting efforts in the medical and pharmacy education domain. This systematic approach ensured a comprehensive and consistent data collection process, facilitating a thorough analysis and synthesis of the relevant literature.

Synthesis of results

The narrative synthesis process commenced with a thorough reading and re-reading of the extracted data from each included study to gain an in-depth understanding of the key findings related to future trends in medical and pharmacy education. Two reviewers (initials) independently coded and categorized these findings into broad thematic areas using a standardized data extraction form.

These emerging thematic areas were then further analyzed and refined through an iterative process of discussion and consensus between the two reviewers. Similar themes were combined, while divergent themes were reorganized into distinct categories representing overarching trends. We adopted a narrative synthesis approach, as defined by Popay et al. (2006), to thematically group findings across diverse study types without meta-analysis. This involved iterative coding, theme development, and conceptual mapping.

Analytical Strategies: To enhance the credibility of the analysis, the reviewers employed several analytical strategies within the narrative synthesis framework:

1. Providing robust descriptions of the characteristics and methodologies of the included studies to establish context.
2. Exploring relationships within and between the identified trends through conceptual mapping techniques.
3. Assessing the trustworthiness and insights of each data source based on factors such as study design and relevance to the review question.
4. Identifying and explaining any contradictory data or conflicting perspectives across studies.
5. Critically examining the strengths and limitations of the evidence underlying each identified trend.

The final synthesis offers a comprehensive textual summary and conceptual model of the key emerging trends expected to shape the future trajectory of medical and pharmacy education. These trends were further categorized, contextualized, and discussed in relation to existing literature and theoretical frameworks (See Table 2).

Quality appraisal

In line with the scoping review methodology, a formal quality appraisal of the included studies was not undertaken. The primary objective was to map the breadth and depth of the literature pertaining to the review topic, aiming to provide a comprehensive overview of the available evidence rather than critically appraising the quality of individual studies.

Reporting

This scoping review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist to ensure the specificity and comprehensiveness of the study's findings [21]. Conformity to this widely recognized reporting guideline enhances transparency and facilitates the clear and comprehensive dissemination of the review outcomes, enabling effective communication of the findings to relevant stakeholders.

Results

Selection of sources of evidence

Our electronic search yielded a total of 926 studies from a variety of databases. These studies were distributed across different databases as follows: PubMed ($n=287$), Scopus ($n=323$), and Web of Science ($n=316$). After eliminating duplicate entries, we were left with 419 unique studies.

After conducting the literature review, the studies were subjected to a rigorous selection process. This involved thoroughly reviewing the titles and abstracts of the studies to ensure their relevance and suitability for analysis. For a visual representation of the systematic literature

review process and study selection flow, please refer to Fig. 1. Note: Some studies focused exclusively on either medical or pharmacy education. These were included as long as they addressed future trends relevant to that discipline.

Characteristics of sources of evidence

Among the 75 studies subjected to full-text assessments, 22 were determined to align with the research title's inclusion and exclusion criteria. These 22 studies were consequently selected as the final cohort for our study. Among the 22 included studies, 18 (82%) discussed technological advancements such as AI and virtual reality, while 12 (55%) focused on curricular reforms or interdisciplinary collaboration."

Results of individual sources of evidence

Table 1 provides a summary of the included studies, including relevant details and key findings. This summary provides a brief and comprehensive overview of the selected studies, serving as a quick reference for understanding their content and contribution to the research topic.

Synthesis of results

The synthesis of results revealed several notable trends within Medical and Pharmacy Education. These trends encompass a wide range of topics, including technological advancements, regulatory changes, and shifts in consumer preferences. Table 2; Fig. 2 present a compilation of emerging trends identified in the Medical and Pharmacy education that we included in our Scoping review. Figure 2 illustrates the thematic trends derived from the included studies. These have been organized into domains such as technological innovations (e.g., VR/AR, AI), curricular and pedagogical reforms, interprofessional education, and human-AI collaboration. The figure reflects both macro-level shifts in educational philosophy and specific technological drivers of change.

Social trends

Studies emphasized a shift towards patient-centered care, interprofessional teamwork, and the inclusion of social determinants of health in curricula. There is also growing attention to communication skills, humanistic approaches, and the integration of population health and preventive medicine.

Technological trends

The literature highlighted the rapid integration of AI, VR/AR, simulation, virtual patients, and digital platforms as transformative tools in education. These technologies support personalized, immersive, and competency-based

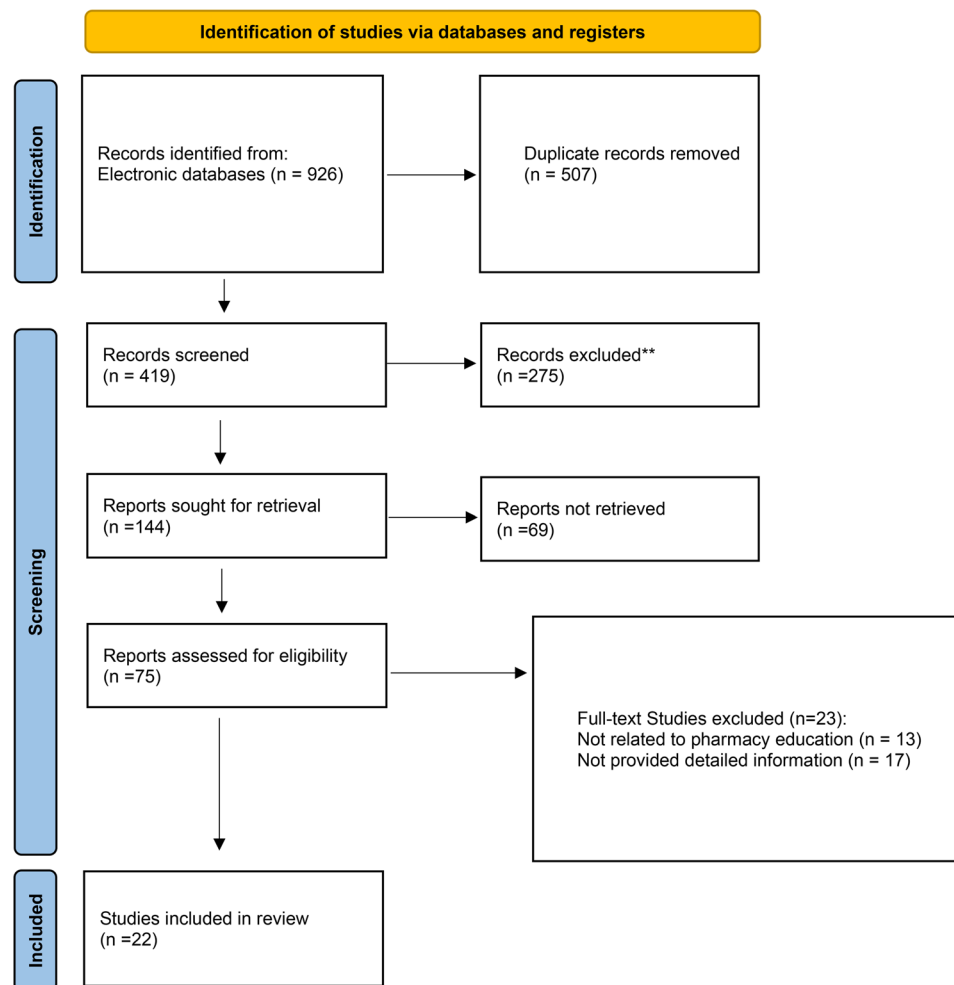


Fig. 1 PRISMA flow diagram of included studies. Note: *Reports not retrieved* ($n = 69$) were due to unavailable full-text access (e.g., paywalls, inaccessible journals, or withdrawal from databases). *Records excluded** ($n = 275$) were excluded during title/abstract screening because they did not meet inclusion criteria (e.g., not related to medical/pharmacy education, not addressing future trends, or insufficient methodological details).*

learning, while also raising concerns about ethical oversight and reliance on AI.

Economic trends

Rising healthcare costs were consistently identified as a driver for reforms in medical and pharmacy education. This includes preparing learners for value-based, cost-effective care delivery and improving understanding of health policy, financing, and resource management.

Political trends

Several studies emphasized the importance of policy reforms and stakeholder engagement, highlighting the role of regulators, universities, and governments in shaping future curricula to respond to global healthcare challenges.

Value-Based trends

Ethical considerations were repeatedly underscored, especially regarding the integration of AI. The need for frameworks that balance technological innovation with empathy, patient safety, transparency, and professional judgment was emphasized as a critical direction for future education.

Discussion

Based on the identified trends—particularly those related to AI integration, interdisciplinary learning, and patient-centered care—several future training priorities emerge. This scoping review presents a holistic perspective on the transformative trends poised to reshape medical and pharmacy education in the coming years. The findings resonate with several other studies that have explored the impact of technological advancements, pedagogical innovations, and evolving healthcare needs on educational practices [41–44]. Although the focus of this

Table 1 A summary of the included studies

No.	References	Country	Article Type	Article Summary
1	[22]	Malaysia	EDITORIAL	The Article discusses the challenges and implications of integrating digital technologies and artificial intelligence in medical education, as well as the need to adapt teaching methods and curricula to prepare future doctors for a technology-driven healthcare environment.
2	[16]	Saudi Arabia	ORIGINAL	The article, written from the perspective of the year 2050, outlines the evolution of 21st-century medical education, highlighting the inefficiencies of the current system and predicting a shift towards shorter, more specialized training within a multidisciplinary framework, emphasizing quality of life in patient care.
3	[23]	Lebanon	ORIGINAL	The medical education community is addressing challenges through educational technology, particularly using virtual patients (VPs), which are interactive patient scenarios. VPs promote deep learning, clinical reasoning, and competency-based education, and their data can support research to improve medical education.
4	[21]	USA	EDITORIAL	The article discusses future trends in medical education, emphasizing the integration of advanced technologies, cost-effective health care delivery, and the development of a global professional identity among students. It highlights the need for competency-based education and the importance of preparing students for efficient and equitable healthcare practices.
5	[24]	UAE	EDITORIAL	The article explores the transformative role of artificial intelligence (AI) in medical education, emphasizing the integration of AI tools, virtual and augmented reality, and gamification to enhance learning experiences and diagnostic precision. It also highlights the need for global accessibility and personalized, adaptive learning systems to prepare future healthcare practitioners effectively.
6	[25]	USA	REVIEW	The article discusses several future trends for medical education, including the integration of artificial intelligence (AI) and virtual reality (VR). AI can enhance personalized learning, diagnostic precision, and ethical awareness, while VR can simulate clinical experiences to improve empathy and clinical skills. These technologies promise to revolutionize medical education by providing adaptive, immersive, and interactive learning environments.
7	[26]	Canada	REVIEW	the main future trend highlighted is the need to move beyond just replicating patient-specific anatomy to also recreating the physiological properties and biomechanical behavior of human tissues through new printing materials, composites, and technologies.
8	[27]	Saudi Arabia	Letter to the Editor	The trends highlighted are the growing role of AI and chatbots in medical education, but with a strong emphasis on human oversight, ethical considerations, rigorous training data and methods, and constant refinement to mitigate the risks and limitations associated with AI technologies in this domain.
9	[28]	USA	EDITORIAL	the editorial highlights the pressing need to revamp medical training at all levels to produce AI-proficient physicians while maintaining core skills, and addressing challenges like equitable access and workforce impacts.
10	[29]	USA	EDITORIAL	The editorial envisions a future medical education model that leverages technology for more engaging, customized, and scalable learning experiences focused on building practical skills, beyond just content delivery.
11	[30]	Saudi Arabia	ORIGINAL	The overarching trends highlighted revolve around strategically integrating AI into all levels of medical training while maintaining clinical competencies, addressing equity challenges, and adapting to AI's impact on the medical workforce landscape across specialties.
12	[31]	Saudi Arabia	ORIGINAL	The article highlights the need for nationally standardized outcomes, integrated curricula, advanced teaching methods, improved assessments, enhanced experiential training, and multi-stakeholder collaboration to advance pharmacy education in Saudi Arabia.
13	[32]	Saudi Arabia	REVIEW	The article highlights the need for personalized, technology-driven learning experiences, skill development beyond traditional curricula, research focus, value-based approaches, and addressing ethical concerns to integrate AI effectively in medical education.
14	[33]	USA	ORIGINAL	In summary, the trends highlight using technology, simulations, mobile apps, and interactive methods to create more engaging, self-directed, competency-based learning aligned with newer healthcare needs and current student learning preferences.
15	[34]	USA	REVIEW	The authors argue that empirical research in these areas is needed to guide the effective and ethical integration of generative AI into medical education curricula and practices.
16	[15]	USA	COLLOQUIUM INTRODUCTION	This study aimed to synthesize the potential opportunities and limitations of generative AI in medical education. It sought to identify prevalent themes within recent literature regarding potential applications and challenges of generative AI in medical education, with the goal of using these insights to guide future areas of exploration and research in this field.

Table 1 (continued)

No.	References	Country	Article Type	Article Summary
17	[35]	Canada	CROSS-SECC-TIONAL STUDY	The key future trend is the integration of AI-related curricula and training into medical education programs to ready graduates for an AI-driven healthcare environment while addressing logistical obstacles in implementing such curricula. The specific formats and pedagogical approaches remain to be determined.
18	[36]	South Korea	REVIEW	The authors synthesize trends from analyzing various innovative educational programs described in the literature that aim to prepare medical students for future healthcare contexts influenced by technological advances, patient diversity, community needs, etc.
19	[37]	Ireland	ORIGINAL	This article highlighted the rise of webinars and e-learning as disruptive but accessible modes of medical education that can promote multi-disciplinary interactions while reducing travel needs and carbon footprints compared to traditional conference models.
20	[38]	Pakistan	EDITORIAL	In summary, the integration of AI language models like ChatGPT in medical education is seen as inevitable, but with a need for robust governance, human oversight, and a balanced approach where AI supplements rather than replaces human input, critical thinking, and originality.
21	[39]	USA	REVIEW	The key trends involve VR becoming a routine part of integrated, multidisciplinary medical training focused on building technical skills as well as humanistic competencies like empathy in a standardized, accessible, and cost-effective manner.
22	[40]	USA	EDITORIAL	In essence, the editorial calls for transformative and forward-looking reforms in medical education to create a workforce prepared for the scientific and technological advancements reshaping healthcare delivery and preventive interventions.

review is on medical and pharmacy education, the identified trends and training needs—such as AI literacy, inter-professional collaboration, and adaptive expertise—are equally relevant to broader health professions education. These insights can inform interdisciplinary curriculum development across healthcare disciplines.

Technological integration and Human-AI collaboration

The integration of artificial intelligence (AI), virtual reality (VR), and augmented reality (AR) technologies emerges as a dominant theme, aligning with the observations of various researchers [45–48]. These technologies offer immense potential for enhancing learning experiences, promoting skill development, and fostering diagnostic precision. However, as highlighted by Davenport and Kalakota [49], the effective adoption of AI in education requires a balanced approach that maintains the development of core clinical competencies and humanistic values.

Several studies emphasize the need for robust ethical frameworks and guidelines to address issues such as data privacy, algorithm transparency, and potential biases in AI systems [50–52]. These concerns echo the findings of this review, underscoring the importance of multi-stakeholder collaboration in developing comprehensive curricula and governance models that optimize human-AI synergies.

Curricular reforms and future workforce Preparation

The identified need for curricular reforms to align with value-based, cost-effective care delivery models resonates

with the perspectives presented by Skochelak and Stack [53]. Their work highlights the importance of equipping future healthcare professionals with a broader skillset encompassing health policy, population health management, and an understanding of social determinants of health.

Furthermore, the emphasis on interprofessional collaboration and communication skills aligns with the recommendations put forth by the Interprofessional Education Collaborative (IPEC) [54]. As healthcare systems become increasingly complex, the ability to collaborate effectively across disciplines and navigate multifaceted care pathways will be essential for the future workforce.

Multidisciplinary approaches and precision medicine

The review’s findings underscore the importance of adopting multidisciplinary approaches and integrating fields such as genomics, biotechnology, and data science into curricula. This aligns with the vision presented by the National Academies of Sciences, Engineering, and Medicine [55], which calls for the cultivation of a “science of healthcare delivery” that leverages diverse disciplinary perspectives to improve patient outcomes and system performance.

Additionally, the need to prepare graduates for the era of precision medicine and data-driven healthcare is echoed by the American Association of Colleges of Pharmacy (AACP) [56]. Their curricular guidelines emphasize the integration of pharmacogenomics, bioinformatics, and data analytics to equip future pharmacists for personalized medicine and evidence-based practice.

Table 2 New trends extracted from the review for the medical and pharmacy education field

No.	New Trends	References
Social		
1	Shift towards personalized/genomics-based treatments, impacting how future doctors are trained.	[22]
2	The curriculum will redefine the outcomes of patient care, focusing not just on diagnosis and treatment but also on quality-of-life issues and the successful reintegration of patients into society.	[16]
3	Rising health care costs will drive reforms in medical education, emphasizing the need to prepare students for efficient care delivery. This includes understanding health policy, population health, and health care financing, and focusing on the social determinants of health.	[21]
4	Curricular changes to prepare students for new value-based, cost-effective healthcare delivery models that address social determinants of health and population health.	[21]
5	Emphasizing the development of skills like communication, social pharmacy, information technology, and medication safety in the curriculum.	[31]
6	Focusing on transitioning the pharmacist's role from product-centered to more patient-centered care.	[31]
7	Medical education will need to focus on developing skills like statistical expertise, communication, teamwork, risk management, and compassion, in addition to factual knowledge.	[32]
8	A humanistic approach to patient safety: • Encouraging humanistic doctors who can better understand patients, appreciate physicians' roles, and build meaningful relationships with patients. • Facilitating collaboration between medical students and other health professionals to ensure patient safety.	[36]
9	Emphasis on "soft skills" like communication, negotiation, and persuasion for technical medical roles in the data economy. The analysis shows a gap between industry demand for these human skills and their lack of focus on academic training.	[15]
10	Shifting focus from just disease diagnosis and treatment to more emphasis on health maintenance, disease prevention, risk management, translational sciences and behavioral sciences.	[40]
11	Continuing medical education (CME) will be replaced by continuing professional development (CPD), focusing not just on clinical updates but also on managerial, social, and personal skills.	[16]
12	A multidisciplinary approach to patient care will be adopted, with allied health care workers playing a more significant role alongside physicians.	[16]
13	Updating curricula to keep pace with rapid advancements in life sciences knowledge enabled by international collaboration, large health data banks, information technology tools, and new data analysis techniques.	[40]
Technological		
14	Increased use of digital technologies like podcasts, videos, mobile apps, video games, simulations, and wearable devices in the educational environment.	[22]
15	AI is being used for making diagnoses by comparing patient data/images with large databases, e.g., facial recognition software for diagnosing genetic syndromes and AI-based dermatology consults.	[22]
16	Increased use of animations, augmented reality, and virtual reality for teaching concepts related to body functions, diseases, etc.	[22]
17	Increased use of virtual patients (VPs) - interactive, multimedia patient scenarios - to address various challenges in medical education.	[23]
18	Using VPs to promote deep learning through active, constructive, and interactive learning activities like summary writing, prioritizing differential diagnoses, etc.	[23]
19	Medical education will increasingly incorporate technologies such as artificial intelligence, robotics, genomics, and nanotechnology. These advancements will enhance diagnostic capabilities, treatment options, and educational methods, including simulation and telemedicine.	[21]
20	Increased use of technology-enabled approaches like virtual patients, simulations, online modules, etc. for teaching and assessment.	[21]
21	AI will be pivotal in medical education, enhancing learning through AI-powered tools, personalized learning experiences, and improving diagnostic precision. This includes AI-driven games, virtual patients, and content-based image retrieval for diagnostic training	[24]
22	Utilizing virtual reality (VR) and augmented reality (AR) technologies to create immersive and interactive learning experiences, enabling students to investigate and participate in simulated clinical scenarios.	[24]
23	Implementing AI-powered games and gamification elements (points, badges, leaderboards) to increase engagement, foster collaboration, and optimize learning outcomes through personalized and adaptive challenges.	[24]
24	Integrating AI training into the medical education curriculum to enhance diagnostic accuracy, enable personalized learning opportunities, and promote ethical awareness in the use of AI technologies in healthcare.	[24]
25	Utilizing VR headsets and head-mounted displays to provide immersive and interactive learning experiences that mimic real-world clinical scenarios and reinforce didactic concepts.	[25]
26	Incorporating gamification elements and AI-powered games into VR experiences to increase student engagement and create personalized, adaptive learning challenges.	[25]

Table 2 (continued)

No.	New Trends	References
27	Increasing the availability, accessibility, and reducing costs of 3D printing technology and expertise to enable wider adoption in medical education programs.	[26]
28	Development of composite and blended printing materials to better mimic the flexibility, elasticity, and tissue properties of biological tissues like skin, organs, vasculature, etc.	[26]
29	Increasing use of chatbots and artificial intelligence (AI) in medical education, but with the need for human monitoring and oversight to address limitations and potential risks of inappropriate or dangerous content generated by AI.	[27]
30	Integrating artificial intelligence (AI) into medical school curricula to train future physicians on how to effectively utilize AI in medical practice.	[28]
31	More use of the “flipped classroom” approach where students prepare by watching lectures/doing pre-work at home, and then come to class for more active case-based learning, problem-solving, and team activities.	[29]
32	Leveraging technologies like video lectures, online platforms, tablets, smartphones, etc. to deliver educational content and facilitate interactive learning.	[40]
33	Integrating artificial intelligence (AI) and advanced analytics into medical curricula to train students on utilizing these technologies in medical practice.	[30]
34	Using advanced teaching methodologies that focus on student self-learning, active learning, and technology integration (e.g., flipped classroom, simulations, blackboard).	[31]
35	AI can provide tailored instructional content and learning experiences based on individual students’ knowledge gaps, learning speeds, and preferences, promoting deeper understanding.	[32]
36	Realistic clinical scenarios using virtual patients and augmented reality can allow students to learn and practice in a risk-free environment.	[32]
37	Medical students must be prepared to adapt to rapid technological advancements in AI and machine learning for healthcare.	[32]
38	Technology-enhanced active learning (TEAL) approaches using games, simulations, and other interactive activities to engage the current generation of medical students.	[33]
39	Use of virtual patient simulations (VPS) to provide students opportunities to practice clinical reasoning and decision-making in a safe environment before live patient encounters.	[33]
40	Use of interactive technologies to teach concepts related to community/primary care medicine needed to meet requirements of the Affordable Care Act.	[33]
41	Exploring virtual environments, electronic health records integration, and virtual anatomy teaching materials alongside clinical case simulations.	[33]
42	Increasing use of computational models and visualizations to understand complex biological, technological, and social systems related to healthcare and medicine.	[15]
43	Greater emphasis on training students to work with data, computational models, and visualizations. As more decision-making relies on analyzing large datasets and interpreting model outputs, there will likely be a need for medical education to teach data literacy and analysis skills.	[15]
44	Providing personalized, contextualized learning tailored to individual student needs.	[15]
45	Preparing students for human-AI collaboration and workflow. With AI increasingly automating certain tasks, medical education may need to focus on training humans for roles that leverage uniquely human capabilities while working alongside AI systems.	[15]
46	Preparing the medical workforce for AI adoption in healthcare	[35]
47	Inclusion of AI curriculum in formal medical education programs	[35]
48	Student-driven learning with advanced technology: • Active learning with individualization facilitated by virtual patients, simulations, augmented reality, etc. • Social interaction and peer learning are enabled by online communities, mobile devices, etc. • Increased accessibility to learning resources regardless of geographic location.	[36]
49	Increased use of large language models like ChatGPT for assisting in medical education and clinical decision-making.	[38]
50	Increased casual and routine use of VR as a supplemental training tool integrated into standard medical curricula and continuing education programs. VR is projected to become more commonplace in medical training.	[39]
51	Increased use of e-learning webinars as an alternative or supplement to traditional conferences and in-person teaching methods like lectures.	[37]
52	Leveraging webinars to promote multi-disciplinary and inter-disciplinary learning by having experts from different subspecialties present on the same topics.	[37]
53	Increasing use of online platforms and open-access educational resources like the “Heart University” mentioned in the paper to disseminate webinars and other e-learning content.	[37]
54	Expansion of multiplayer and interprofessional VR scenarios, allowing learners from different disciplines to interact and practice teamwork in shared virtual clinical cases.	[39]
55	Adopting a more multidisciplinary approach to medical education that integrates different fields like genetics, biotechnology, nanotechnology, 3D printing, etc. to provide more individualized and preventive care.	[29]

Economic

Table 2 (continued)

No.	New Trends	References
56	Rising healthcare costs will drive reforms in medical education, emphasizing the need to prepare students for efficient care delivery. This includes understanding health policy, population health, and health care financing, and focusing on the social determinants of health.	[21]
57	Rising healthcare costs will drive reforms in medical education, emphasizing the need to prepare students for efficient care delivery. This includes understanding health policy, population health, and health care financing, and focusing on the social determinants of health.	[21]
Political		
58	Engaging diverse stakeholders from academia, sciences, health sectors, patient communities, and policymakers in reforming medical education to address future changes.	[40]
Value		
59	Ethical considerations and implementation of controls/limits around the use of AI language models in medical education to prevent the spread of harmful ideas and erroneous information.	[27]
60	Striking a balance between training on AI tools and developing innate clinical skills, to avoid over-reliance on AI at the expense of core medical expertise.	[28]
61	Legal and ethical considerations around properly training physicians on AI usage to meet evolving standards of care and avoid issues like malpractice.	[28]
62	Designing curricula that optimize the combination of AI proficiency and development of innate clinical abilities.	[30]
63	Legal and ethical considerations around properly training physicians on AI usage to meet evolving standards of care and avoid issues like malpractice claims.	[30]
64	Ethical frameworks need to be established to ensure AI algorithms are transparent, fair, and unbiased while addressing issues like data privacy and informed consent.	[32]
65	Developing learners' skills to evaluate AI critically: • Teaching learners critical appraisal skills to assess the accuracy and quality of AI-generated information • Fostering skills to navigate uncertainty and incomplete/biased data from AI Developing curricula to enhance learners' "AI literacy"	[34]
66	Rethinking assessment methodology: • Reconsidering assessment objectives and methods in light of AI's ability to mimic higher-order cognition • Studying the impact of AI usage on assessment validity and implications for competency evaluation	[34]
67	The potential risk of over dependence on AI leads to the degradation of human cognitive abilities for fundamental tasks.	[38]
68	A humanistic approach to patient safety: • Encouraging humanistic doctors who can better understand patients, appreciate physicians' roles, and build meaningful relationships with patients. • Facilitating collaboration between medical students and other health professionals to ensure patient safety.	[36]
69	Early clinical exposure and hands-on experience will be emphasized, with students gaining practical experience from the beginning of their training through programs like the "patient-specialist program."	[16]
70	The length of medical education will be significantly shortened, with students completing a 3-year core medical curriculum after high school, followed by a 2-year higher medical education track (physician, allied health, or medical scientist track), and then a 2-year specialty training program.	[16]

Future needs and required training

Based on the identified trends and insights from the broader literature, several key future needs and required training areas emerge:

1. AI Literacy and Human-AI Collaboration:

Medical and pharmacy curricula must prioritize developing learners' capabilities to effectively collaborate with AI systems. This includes fostering a deep understanding of AI principles, ethical considerations, and the ability to critically evaluate AI-generated information and insights [57].

2. Interprofessional and Teamwork Skills:

As healthcare delivery becomes increasingly collaborative and team-based, interprofessional education (IPE) and training in effective teamwork and communication will be crucial [58]. Simulations,

case-based learning, and interprofessional clinical experiences can help cultivate these essential competencies.

3. **Data Analytics and Decision-Making:** With the growing emphasis on evidence-based practice and data-driven decision-making, training in data analytics, biostatistics, and critical appraisal of research findings will be paramount [59]. Learners must develop the ability to interpret complex data and translate insights into informed clinical decisions.
4. **Adaptive Expertise and Lifelong Learning:** Given the rapid pace of change in healthcare, cultivating adaptive expertise and a commitment to lifelong learning will be essential for future professionals [60]. Curricula should emphasize metacognitive skills,

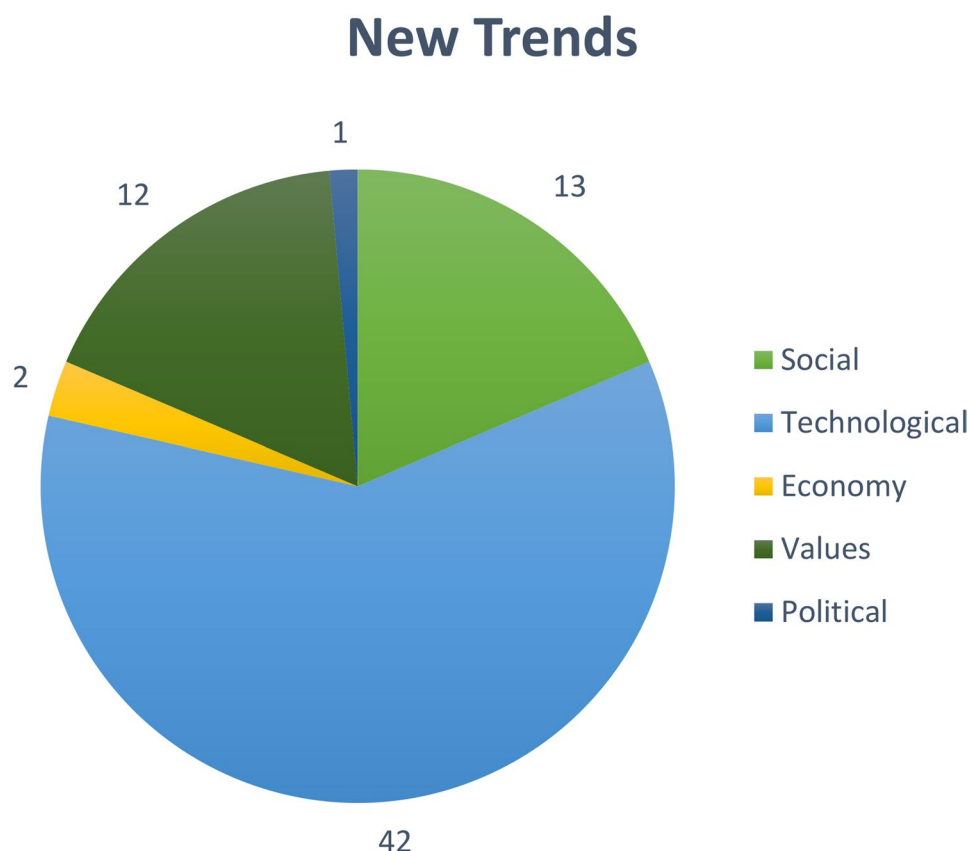


Fig. 2 New Trends extracted from the review for the Medical and Pharmacy Education

self-directed learning strategies, and the ability to navigate and synthesize diverse knowledge sources.

5. **Patient-Centered Care and Empathy:** While embracing technological advancements, maintaining a strong focus on patient-centered care, empathy, and effective communication with patients and caregivers will be crucial [61]. Training in narrative medicine, reflective practice, and emotional intelligence can foster these humanistic competencies.
6. **Leadership and Change Management:** As healthcare systems undergo transformations, future healthcare professionals will need to develop leadership skills and the ability to navigate and drive organizational change [62]. Training in change management, systems thinking, and strategic planning can equip learners for these essential roles.
7. **Entrepreneurship and Innovation:** With the rise of digital health, personalized medicine, and disruptive healthcare models, fostering an entrepreneurial mindset and innovation skills will be valuable [63]. Curricula can incorporate design thinking, lean startup methodologies, and opportunities for developing and pitching innovative solutions.

To address these future needs, educational institutions, healthcare organizations, and regulatory bodies must collaborate to develop comprehensive, forward-looking curricula and training programs. Continuous evaluation and adaptation will be necessary to ensure that medical and pharmacy education remains relevant and effective in the rapidly evolving healthcare landscape.

By embracing technological innovations while prioritizing adaptive, future-ready competencies, medical and pharmacy education can produce a workforce equipped to navigate the complexities of modern healthcare, deliver high-quality patient-centered care, and drive transformative changes in the healthcare ecosystem.

Strengths and limitations

While this scoping review provides a comprehensive overview of the emerging trends and future directions in medical and pharmacy education, it is important to acknowledge several limitations that should be considered when interpreting the findings.

First, the review relied solely on published academic literature obtained through database searches. Relevant insights from grey literature sources, such as industry reports, white papers, or government publications, were not included in the search strategy. Given the rapidly

evolving nature of technological advancements and educational innovations, these sources may contain valuable information and perspectives that could further enrich the understanding of future trends.

Second, the search was limited to studies published between April 2014 and April 2024. While this timeframe aimed to capture the most recent and relevant literature, it is possible that seminal or foundational works published before 2014 were inadvertently excluded from the review. Additionally, given the continuous emergence of new research, publications released after April 2024 were not considered, potentially omitting the latest developments in the field.

Third, the review focused specifically on medical and pharmacy education, excluding literature that explored future trends in the broader healthcare education landscape or other allied health professions. While this narrow scope allowed for an in-depth analysis of the target disciplines, it may have overlooked relevant insights from related fields that could inform or influence the future trajectory of medical and pharmacy education.

Fourth, the study selection process relied on the subjective assessment of the reviewers in determining the eligibility and relevance of studies based on the predefined inclusion and exclusion criteria. Despite efforts to maintain consistency and objectivity, there is a possibility that some relevant studies may have been inadvertently excluded or irrelevant studies included due to differences in interpretation or human error.

Finally, the synthesis of results and identification of trends were based on a narrative approach, which inherently involves a degree of subjectivity. While analytical strategies were employed to enhance the credibility and trustworthiness of the findings, the potential for researcher bias in interpreting and synthesizing the data cannot be entirely eliminated.

It is crucial to interpret the findings of this scoping review within the context of these limitations. Future research efforts could address these limitations by incorporating a broader range of literature sources, expanding the scope to include related healthcare disciplines, and employing more rigorous analytical techniques to synthesize and validate the identified trends. Additionally, the selection of databases—while covering a broad spectrum—may have excluded relevant literature from other sources such as Medline or CINAHL. Future studies may benefit from expanding the database range to include additional health and education-focused repositories.

Conclusion

This scoping review provides a comprehensive overview of the emerging trends expected to shape the future of medical and pharmacy education. The key findings highlight the transformative impact of technological

innovations like artificial intelligence, virtual reality, and augmented reality in enhancing educational delivery and learning experiences. However, the effective integration of these technologies requires a balanced approach that maintains core clinical competencies and humanistic values.

Beyond technology, the review emphasizes the need for curricular reforms to align education with evolving healthcare models focused on value-based, cost-effective care delivery. Developing skills in areas like interprofessional collaboration, population health management, and understanding social determinants of health is crucial for the future workforce.

The review also underscores the importance of adopting multidisciplinary approaches and integrating fields like genomics and data science to prepare graduates for precision medicine and data-driven healthcare. Addressing the changing disease burden through preventive care and chronic disease management education is another key trend.

While subject to certain limitations, this review offers valuable insights to guide educational institutions, policymakers, and healthcare organizations in proactively adapting their programs to the identified trends. Embracing innovation while prioritizing adaptive, future-ready competencies will be critical to ensuring the continued relevance and effectiveness of medical and pharmacy education in the rapidly evolving healthcare landscape.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12909-025-08037-2>.

Supplementary Material 1.

Acknowledgements

We extend our sincere gratitude to all the researchers and authors whose valuable contributions form the foundation of this scoping review. Their insights and findings have been instrumental in shaping our understanding of future trends within Medical and Pharmacy Education.

Authors' contributions

MB and FS conceived the study. MB, BF, NZ and FS collected the data. MB, BF, NZ, FS, SN, AK, RM, AZ analyzed the data and drafted the manuscript. All authors read and approved the final manuscript.

Funding

This research was supported by the Tehran University of Medical Science. The funder had no role in the conceptualization, design, data collection, analysis, decision to publish, or preparation of the manuscript.

Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Not applicable. This study did not involve human participants, human data or human tissue.

Consent for publication

Not applicable. This manuscript does not contain data from any individual person.

Competing interests

The authors declare no competing interests.

Received: 24 June 2024 / Accepted: 19 September 2025

Published online: 30 October 2025

References

- Swanwick T. Understanding medical education. In: Swanwick T, Forrest K, O'Brien BC, editors. Understanding medical education: Evidence, Theory, and practice. 2nd ed. Hoboken (NJ): Wiley-Blackwell; 2018. p. 1–6.
- Okuda Y, Bryson EO, DeMaria S Jr, Jacobson L, Quinones J, Shen B, et al. The utility of simulation in medical education: what is the evidence? *Mt Sinai J Med*. 2009;76(4):330–43.
- Marinopoulos SS, Dorman T, Ratanawongsa N, Wilson LM, Ashar BH, Magaziner JL et al. Effectiveness of continuing medical education. *Evid Rep Technol Assess (Full Rep)*. 2007;(149):1–69.
- Pearson ML, Hubball HT. Curricular integration in pharmacy education. *Am J Pharm Educ*. 2012. <https://doi.org/10.5688/ajpe7610204>.
- van der Niet AG, Bleakley A. Where medical education meets artificial intelligence: does technology care? *Med Educ*. 2021;55(1):30–6.
- Irby DM, Cooke M, O'Brien BC. Calls for reform of medical education by the Carnegie Foundation for the Advancement of Teaching: 1910 and 2010. *Acad Med*. 2010;85(2):220–7.
- Lucey CR. Medical education: part of the problem and part of the solution. *JAMA Intern Med*. 2013;173(17):1639–43.
- Sridharan K, Sequeira RP. Artificial intelligence and medical education: application in classroom instruction and student assessment using a pharmacology & therapeutics case study. *BMC Med Educ*. 2024;24(1):431.
- Ruiz JG, Mintzer MJ, Leipzig RM. The impact of e-learning in medical education. *Acad Med*. 2006;81(3):207–12. <https://doi.org/10.1097/00001888-200603000-00002>.
- Salter SM, Karia A, Sanfilippo FM, Clifford RM. Effectiveness of e-learning in pharmacy education. *Am J Pharm Educ*. 2014. <https://doi.org/10.5688/ajpe78483>.
- Aziz MHA, Rowe C, Southwood R, Nogid A, Berman S, Gustafson K. A scoping review of artificial intelligence within pharmacy education. *Am J Pharm Educ*. 2023;87(3):100615. <https://doi.org/10.5688/ajpe100615>.
- Cisneros RM, Salisbury-Glennon JD, Anderson-Harper HM. Status of problem-based learning research in pharmacy education: a call for future research. *Am J Pharm Educ*. 2002;66(1):19–26.
- Frenk J, Chen L, Bhutta ZA, Cohen J, Crisp N, Evans T, et al. Health professionals for a new century: transforming education to strengthen health systems in an interdependent world. *Lancet*. 2010;376(9756):1923–58. [https://doi.org/10.1016/S0140-6736\(10\)61854-5](https://doi.org/10.1016/S0140-6736(10)61854-5).
- Khan O, Parvez M, Kumari P, Parvez S, Ahmad S. The future of pharmacy: how AI is revolutionizing the industry. *Intell Pharm*. 2023;1(1):32–40.
- Börner K, Rouse WB, Trunfio P, Stanley HE. Forecasting innovations in science, technology, and education. *Proc Natl Acad Sci U S A*. 2018;115(50):12573–81. <https://doi.org/10.1073/pnas.1802913115>.
- Zaheer Qureshi A. From the year 2050; a glimpse of medical education in the future. *J Pak Med Assoc*. 2014;64(3):327–30.
- Abd-Alrazaq A, AlSaad R, Alhuwail D, Ahmed A, Healy PM, Latifi S, et al. Large Language models in medical education: opportunities, challenges, and future directions. *JMIR Med Educ*. 2023;9(1):e48291. <https://doi.org/10.2196/48291>.
- Masters K. Artificial intelligence in medical education. *Med Teach*. 2019;41(9):976–80. <https://doi.org/10.1080/0142159X.2019.1595557>.
- Das S, Dey R, Nayak AK. Artificial intelligence in pharmacy. *Indian J Pharm Educ Res*. 2021;55(2):304–18. <https://doi.org/10.5530/ijper.55.2.59>.
- Medina MS, Plaza CM, Stowe CD, Robinson ET, DeLander G, Beck DE. Center for the Advancement of Pharmacy Education 2013 educational outcomes. *Am J Pharm Educ*. 2013. <https://doi.org/10.5688/ajpe778162>.
- Peters MDJ, Marnie C, Tricco AC, Pollock D, Munn Z, Alexander L, et al. Updated methodological guidance for the conduct of scoping reviews. *JBIM Evid Synth*. 2020;18(10):2119–26. <https://doi.org/10.1112/JBISIR-D-19-00349>.
- Malik AS. Digital technology, artificial intelligence and future of medical education. *J Univ Med Dent Coll*. 2021;12(2):v–vi. <https://doi.org/10.37723/jumdc.v12i2.653>.
- Berman NB, Durning SJ, Fischer MR, Huwendiek S, Triola MM. The role for virtual patients in the future of medical education. *Acad Med*. 2016;91(9):1217–22. <https://doi.org/10.1097/ACM.0000000000001146>.
- Naqvi WM, Sundus H, Mishra G, Muthukrishnan R, Kandakurti PK. AI in medical education curriculum: the future of healthcare learning. *Eur J Ther*. 2024;30(2):e23–5. <https://doi.org/10.58600/eurjther1995>.
- Coyne L, Merritt TA, Parmentier BL, Sharpton RA, Takemoto JK. The past, present, and future of virtual reality in pharmacy education. *Am J Pharm Educ*. 2019;83(3):281–90. <https://doi.org/10.5688/ajpe6783>.
- Garcia J, Yang Z, Mongrain R, Leask RL, Lachapelle K. 3D printing materials and their use in medical education: a review of current technology and trends for the future. *BMJ Simul Technol Enhanc Learn*. 2018;4(1):27–40. <https://doi.org/10.1136/bmjstel-2017-000234>.
- Daungsupawong H, Wiwanitkit V. ChatGPT and the future of medical education: correspondence. *J Taibah Univ Med Sci*. 2024;19(2):248–9. <https://doi.org/10.1016/j.jtumed.2023.12.003>.
- Bohler F, Aggarwal N, Peters G, Taranikanti V. Future implications of artificial intelligence in medical education. *Cureus*. 2024;16(1):e57391. <https://doi.org/10.7759/cureus.57391>.
- Williams DE. The future of medical education: flipping the classroom and education technology. *Ochsner J*. 2016;16(1):14–5 PMID:27046464.
- Fayoum AG, Hajjar AF. Advanced learning analytics in academic education: academic performance forecasting based on an artificial neural network. *Int J Semant Web Inf Syst*. 2020;16(3):70–87. <https://doi.org/10.4018/IJSWIS.2020070104>.
- Aljadhey H, Asiri Y, Albogami Y, Spratto G, Alshehri M. Pharmacy education in Saudi Arabia: a vision of the future. *Saudi Pharm J*. 2017;25(1):88–92. <https://doi.org/10.1016/j.jsps.2016.02.009>.
- Mir MM, Mir GM, Raina NT, Mir SM, Miskeen E, et al. Application of artificial intelligence in medical education: current scenario and future perspectives. *J Adv Med Educ Prof*. 2023;11(3):133–40. <https://doi.org/10.30476/JAMP.2023.97815.1780>.
- McCoy L, Pettit RK, Lewis JH, Bennett T, Carrasco N, Brysacz S, et al. Developing technology-enhanced active learning for medical education: challenges, solutions, and future directions. *J Am Osteopath Assoc*. 2015;115(4):202–11. <https://doi.org/10.7556/jaoa.2015.042>.
- Preiksaitis C, Rose C. Opportunities, challenges, and future directions of generative artificial intelligence in medical education: scoping review. *JMIR Med Educ*. 2023;9(1):e50752. <https://doi.org/10.2196/50752>.
- Puccchio A, Rathagiriannan R, Caton N, Garicsak P, Del Papa J, Vo V, et al. The need for artificial intelligence curriculum in medical education: a Canadian cross-sectional study of future oncology trainees. *J Clin Oncol*. 2022;40(16suppl):e18591. https://doi.org/10.1200/JCO.2022.40.16_suppl.e18591.
- Han ER, Yeo S, Kim MJ, Lee YH, Park KH, Roh H. Medical education trends for future physicians in the era of advanced technology and artificial intelligence: an integrative review. *BMC Med Educ*. 2019;19(1):460. <https://doi.org/10.1186/s12909-019-1891-2>.
- McMahon CJ, Tretter JT, Faulkner T, Kumar RK, Redington AN, Windram JD. Are e-learning webinars the future of medical education? An exploratory study of a disruptive innovation in the COVID-19 era. *Cardiol Young*. 2021;31(5):734–43. <https://doi.org/10.1017/S1047951120004159>.
- Arif TB, Munaf U, Ul-Haque I. The future of medical education and research: is ChatGPT a blessing or blight in disguise? *Med Educ Online*. 2023. <https://doi.org/10.1080/10872981.2023.2181052>.
- Mistry D, Brock CA, Lindsey T. The present and future of virtual reality in medical education: a narrative review. *Cureus*. 2023;15(12):e39045. <https://doi.org/10.7759/cureus.39045>.
- Nicogossian A, Stabile B, Kloiber O, Septimus E. The future of medical education and practice. *World Med Health Policy*. 2017;9(2):162–77. <https://doi.org/10.1002/wmh3.231>.
- Wartman SA, Combs CD. Medical education must move from the information age to the age of artificial intelligence. *Acad Med*. 2018;93(8):1107–9. <https://doi.org/10.1097/ACM.0000000000002044>.
- Ellaway RH, Topps D, Olmberg M, Brauer D, Tsoh K, Haag M. Emerging trends in medical education and distributed communities of practice. *J Contin Educ Health Prof*. 2018;38(3):181–8. <https://doi.org/10.1097/CEH.0000000000000206>.

43. Ellaway RH, Topps D, Rochon PA. Emerging technologies and the application of emerging learning theory: a frontier for medical education research. *Acad Med*. 2019;94(6):793–8. <https://doi.org/10.1097/ACM.0000000000002737>.
44. Shafiq A, Rashid M, Azmatullah A, Khan RA, Minhas FA. Future of medical education and the role of emerging technologies: challenges and opportunities. *Med Educ Online*. 2021;26(1):1896716. <https://doi.org/10.1080/10872981.2021.1896716>.
45. Zhu E, Kaufman M, Hayat A, Hine E, Zaidi NW, Jiang B. Artificial intelligence in medical education: a review of existing applications and future directions. *Acad Med*. 2022;97(10):1442–50. <https://doi.org/10.1097/ACM.0000000000004802>.
46. Pottle J. Virtual reality and the transformation of medical education. *Future Healthc J*. 2019;6(3):181–5. <https://doi.org/10.7861/fhj.2019-0036>.
47. Haag M, Friedrich G, Ellaway R. Exploring the use of virtual reality in medical education: a scoping review protocol. *J Med Educ Curric Dev*. 2021;8:23821205211050860. <https://doi.org/10.1177/23821205211050861>.
48. Hussain R, Zaheer R, Kanesvaran R, Ng HK, Lim A. Artificial intelligence in medical education: a systematic review. *Appl Sci*. 2022;12(11):5574. <https://doi.org/10.3390/app12115574>.
49. Davenport TH, Kalakota R. The potential for artificial intelligence in healthcare. *Future Healthc J*. 2019;6(2):94–8. <https://doi.org/10.7861/futurehosp.6-2-94>.
50. Emanuel EJ, Wachter RM. Artificial intelligence in health care: overcoming the ethical obstacles. *Ann Intern Med*. 2023;176(1):81–8. <https://doi.org/10.7326/M22-2048>.
51. Char DS, Shah NH, Magnus D. Implementing machine learning in health care—addressing ethical challenges. *N Engl J Med*. 2018;378(11):981–3. <https://doi.org/10.1056/NEJMp1714229>.
52. Denton P, Lingard R, Hsu AY, Cyr K, Bernstein J, Buckeridge DL, et al. The need for an ethical framework for artificial intelligence in medical education. *Acad Med*. 2022;97(10):1451–7. <https://doi.org/10.1097/ACM.0000000000004899>.
53. Skochelak SE, Stack SJ. Creating the medical schools of the future. *Acad Med*. 2017;92(1):16–9. <https://doi.org/10.1097/ACM.0000000000001160>.
54. Interprofessional Education Collaborative. Core competencies for interprofessional collaborative practice: 2016 update. Washington (DC): Interprofessional Education Collaborative; 2016.
55. National Academies of Sciences, Engineering, and Medicine. A smarter National workforce to capitalize on the capabilities of data science: a workshop. Washington (DC): National Academies; 2021. <https://doi.org/10.17226/26050>.
56. American Association of Colleges of Pharmacy. Curricular requirements for the professional program in pharmacy leading to the Doctor of pharmacy degree. Chicago (IL): American Association of Colleges of Pharmacy; 2020.
57. Huser V, Chalian H, Babalola K, Rimer Z, Ulanovic M, Bykov Y, et al. Developing artificial intelligence literacy in health professions education: a scoping review. *Acad Med*. 2023;98(6):907–16. <https://doi.org/10.1097/ACM.00000000000005114>.
58. Breitbach AP, Sargeant J, Wood DF, Awan R. Roles and activities of interprofessional education coordinators in the United States and Canada. *J Interprof Care*. 2019;33(6):748–57. <https://doi.org/10.1080/13561820.2019.1589068>.
59. Celi LA, Davidzon G, Williams A, Napolitano A, Scott S, Cinel J, et al. Bridging health data and analytics education to promote workforce diversity and inclusivity for emerging roles in health systems: a perspective. *J Am Med Inf Assoc*. 2023;30(1):83–90. <https://doi.org/10.1093/jamia/ocac165>.
60. Mylopoulos M, Kulasegaram K, Woods NN. Developing the experts we need: fostering adaptive expertise through education. *J Eval Clin Pract*. 2018;24(3):674.
61. Neumann M, Edelhauser F, Tauschel D, Fischer MR, Wirtz M, Woopen C, et al. Empathy decline and its reasons: a systematic review of studies with medical students and residents. *Acad Med*. 2011;86(8):996–1009.
62. Sadri AM, Saeed AM, Hosseini H, Beikzadeh S, Mirzaei A. Leadership during the COVID-19 pandemic: a systematic review of challenges, perspectives, and lessons for healthcare leaders. *BMC Health Serv Res*. 2022;22(1):823.
63. Siren A, Donders R, Vanselow M, Smit C. Healthcare entrepreneurship education: state-of-the-art overview and future directions. *Med Educ Online*. 2023;28(1).

Publisher's note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.