








# Mapping the Landscape: A Systematic Review of Technology Trends in Medical Education and Competency Development

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**Abstract:** Medical education has undergone significant transformations, driven by rapid technological advancements. This systematic review aims to map and analyze educational technology trends from the late 1970s to 2024, tracing their evolution and their impacts on competency development. Following PRISMA guidelines, a comprehensive search was conducted across seven databases in August 2024, yielding 18 studies published between 1978 and 2024 for qualitative, thematic synthesis. The findings indicate that technology integration has evolved through distinct trends. While simulation-based approaches were most frequently reported to enhance clinical reasoning and psychomotor skills, blended learning was highlighted for enabling flexible delivery, and other technologies, such as e-learning platforms and Web 2.0 tools, also played significant roles in supporting knowledge acquisition and collaborative learning. Despite these benefits, high costs, infrastructure limitations, and the need for specialized faculty training were identified as persistent barriers to adoption. In conclusion, the literature review indicates that technological trends have enriched medical education by fostering interactive, accessible, and flexible learning environments. Future strategies must therefore focus on developing scalable, cost-effective solutions. A dedicated systematic review of AI's trajectory and impact is strongly recommended as a critical next step, building upon the historical foundation laid by this study.

**Keywords:** medical education, educational technology, simulation training, blended learning, computer-assisted instruction, systematic review

## Introduction

The practical training of healthcare students and professionals is a critical determinant of the quality and safety of patient care in modern medical systems. In recent decades, this foundational field has undergone a profound transformation, driven by the relentless pace of technological innovation. This shift from a paradigm rooted in traditional classroom instruction and apprenticeships toward digitally enhanced learning environments presents both unprecedented opportunities and significant implementation challenges for educational institutions globally.<sup>1,2</sup>

The integration of digital tools is revolutionizing the delivery of medical knowledge and skills. A wide array of technologies—from simulation-based learning and virtual reality (VR) to e-learning platforms, mobile applications, and more recently, artificial intelligence (AI) encompassing adaptive learning and generative AI—has been increasingly adopted, with numerous studies demonstrating their potential to improve knowledge acquisition, clinical reasoning, and psychomotor skills.<sup>3,4</sup> Despite this promising potential, the practical and sustainable integration of these technologies into medical curricula remains a complex undertaking. Significant barriers persist, including high associated costs,

infrastructural limitations, a lack of specialized faculty training, and insufficient empirical evidence for the long-term efficacy of many newer tools.<sup>5,6</sup> These challenges often hinder technologies from progressing beyond the experimental “innovation” stage to achieving scalable and sustainable adoption.<sup>7</sup>

Consequently, educators, administrators, and policymakers often face considerable uncertainty when making strategic decisions about which technologies are most effective, cost-efficient, and aligned with long-term educational outcomes.<sup>8</sup> This decision-making process is further complicated by a body of literature that, while rich in focused studies, lacks a comprehensive and longitudinal synthesis. Specifically, there is a conspicuous gap in understanding the broader trajectory of technological trends over time and in identifying which tools have demonstrated the most transformative and lasting impact on medical education.<sup>9</sup> This gap is particularly salient in the context of rapidly emerging fields like AI, which are transforming educational practices but lack comprehensive historical contextualization within the broader evolution of medical education technology.

Previous systematic reviews have made valuable contributions but have typically concentrated on specific technological subsets or constrained timeframes. For instance, some reviews have focused exclusively on virtual patients,<sup>10</sup> while others have compared online and offline learning modalities<sup>11</sup> or examined the efficacy of a single technology, such as VR.<sup>12</sup> While these focused approaches provide depth in their respective niches, they leave an overarching gap in the literature.<sup>13</sup> A holistic, longitudinal analysis that maps the evolution of educational technology from the early days of computer-assisted instruction to the contemporary era is necessary to contextualize current innovations and inform future strategic directions. To address this identified gap, this systematic review aims to provide a comprehensive longitudinal analysis of technology trends in medical science education from 1978 to 2024. The primary objectives are to:

1. Systematically identify and categorize the most influential educational technologies adopted during this period.
2. Analyze their reported effects on learning outcomes, competency development, and educational practices.
3. Synthesize the recurring challenges, strengths, and weaknesses associated with their integration.

By offering this historical perspective and synthesizing evidence across nearly five decades, this review provides a unique evidence base to guide educators, curriculum designers, and policymakers in making informed, strategic investments in educational technology. It ultimately seeks to contribute to the overarching goal of maximizing academic return on investment and to equip future healthcare professionals with the competencies required in an increasingly digital healthcare landscape.

## Materials and Methods

This systematic review addressed specific research questions by following a structured, reproducible search and screening process in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.<sup>14</sup> The review was designed to include studies exploring the use of emerging technology trends in medical education. Studies were systematically identified, reviewed, and coded for inductive thematic synthesis. In total, 18 studies met the inclusion criteria for the qualitative synthesis.

## Search Strategy

The systematic review was conducted according to PRISMA guidelines. In August 2024, the following electronic databases were searched: Scopus, ERIC, Web of Science, PubMed, ScienceDirect, PsycInfo, and JSTOR. The search covered studies published between 1978 and 2024, corresponding to the introduction of computer-assisted instruction in medical education (late 1970s) and continuing through the contemporary era of digital innovation.

A comprehensive search query was developed using a combination of MeSH terms and Boolean operators, incorporating keywords such as “new trend”, “e-learning”, and “medical education”. Synonyms for “new trend” included “emerging trend”, “evolving trend”, “novel trend”, “contemporary trend”, and “current trend”. The medical education context was captured using terms such as “medical education”, “clinical education”, “surgical education”, “health education”, and related phrases. E-learning-related terms included “online learning”, “distance learning”, “blended learning”, “technology-enhanced learning”, “virtual reality”, and “computer-assisted instruction”. For example, in

Scopus, the following query was applied: (“new trend” OR “emerging trend” OR “evolving trend” OR “novel trend” OR “contemporary trend\*” OR “recent trend\*” OR “current trend\*”) AND (“clinical education” OR “surgical education” OR “health education” OR “dental education” OR “medical education” OR “medical training” OR “medical curriculum”) AND (“e-learning” OR “online learning” OR “distance learning” OR “blended learning” OR “hybrid learning” OR “technology-enhanced learning” OR “computer-assisted instruction” OR “virtual reality”).

While the core search concepts remained consistent, the specific query syntax (including the use of MeSH terms, keywords, and field tags) was adapted to the requirements of each database to optimize retrieval. The full search strategy for all databases is provided in [Supplementary File 2](#).

## Inclusion and Exclusion Criteria

Inclusion criteria required that studies specifically address emerging trends in e-learning or technology-enhanced learning in medical education settings. Studies of any country, language, or publication date were considered if they were peer-reviewed journal articles or doctoral dissertations. Exclusion criteria were applied to studies not directly related to e-learning in medical education, as well as editorials, commentaries, book chapters, and articles lacking a primary focus on novel technology trends or innovation. Studies specifically address e-learning or technology-enhanced learning trends, with an emphasis on technologies characterized as “emerging”, “novel”, or “innovative” within the context of their publication period.

## Selection and Coding Process

A total of 1530 records were retrieved, with 604 duplicates removed, resulting in 926 titles and abstracts screened. Of these, 878 articles not related to new e-learning trends in medical education were excluded. Full-text reviews of 48 articles were conducted, leading to the exclusion of 30 articles after applying relevance criteria. Eighteen studies remained and were included in the final qualitative analysis.

The study selection and data extraction were performed by two independent reviewers to minimize bias. The process began with a calibration exercise in which both reviewers independently applied the inclusion criteria and extraction protocol to a pilot sample of 5 studies. They then met to compare their results, resolving any differences through discussion to ensure a consistent approach. Following this calibration, the reviewers separately screened the remaining titles/abstracts and full texts, and independently extracted data from the included studies. Throughout the main phase, any disagreements were documented and resolved by consensus, with a third senior reviewer consulted if needed.

## Qualitative Analysis

For the scope of this review, “educational technology” is defined as the systematic application of knowledge and resources to create tools and environments that facilitate learning. This encompasses both overarching technological paradigms (eg, e-learning, simulation-based learning) and the specific tools that instantiate them (eg, the Moodle LMS, Zoom software). Furthermore, “Web 2.0” is operationalized as the second generation of web development that emphasizes user-generated content, interoperability, and participatory culture, which in an educational context includes tools such as blogs, wikis, and social media platforms that enable collaborative learning.

The included studies were analyzed and coded according to predefined parameters, including: the educational technology or tool described; its application and context in medical education; reported learning outcomes or educational impacts; and documented strengths, weaknesses, and implementation challenges. Thematic analysis was conducted to identify, analyze, and report patterns within the data. The coding process was collaborative and iterative. An initial codebook was developed by two authors after a preliminary review of a subset of included studies. These two authors then independently applied the codebook to the complete set of studies. To ensure coding consistency, the two authors independently coded the studies, and any discrepancies were resolved through discussion and consensus with the research team. The analysis was facilitated by Microsoft Excel for data organization and management. The initial codes were subsequently grouped into broader thematic categories to structure the synthesis presented in the results.

## Search Outcome

The PRISMA flow diagram (Figure 1) summarizes the search and selection process. Of the 1530 retrieved records, 926 titles and abstracts were screened after duplicates were removed. Following the exclusion of 878 irrelevant titles and assessment of 48 full texts, a final set of 18 studies was included in the qualitative synthesis. Table 1 summarizes the characteristics of the included studies.

## Quality Assessment

The methodological quality of each included study was assessed using standardized appraisal tools appropriate to the study design: STROBE for observational and descriptive studies, MMAT for mixed-methods studies, and the CASP Cohort Study checklist for cohort studies. Two independent reviewers (the first and second authors) conducted the assessments and resolved discrepancies through discussion with a research methodology expert to ensure high rigor and reliability.

## Data Extraction

Data were extracted using structured forms in Microsoft Excel. Extracted variables included author, publication year, country, study design, medical discipline, and technology type and application (Table 1). A second dataset (Table 2) summarizes technology trends and examples applied in medical education from 1978 to 2024, providing a longitudinal perspective on technological evolution.

## Results

### Descriptive Data of the Reviewed Articles

The data from 18 articles relevant to the objectives of this study were extracted and analyzed. The year 2021 represented the peak of publication activity, with five articles, reflecting heightened scholarly attention likely associated with the

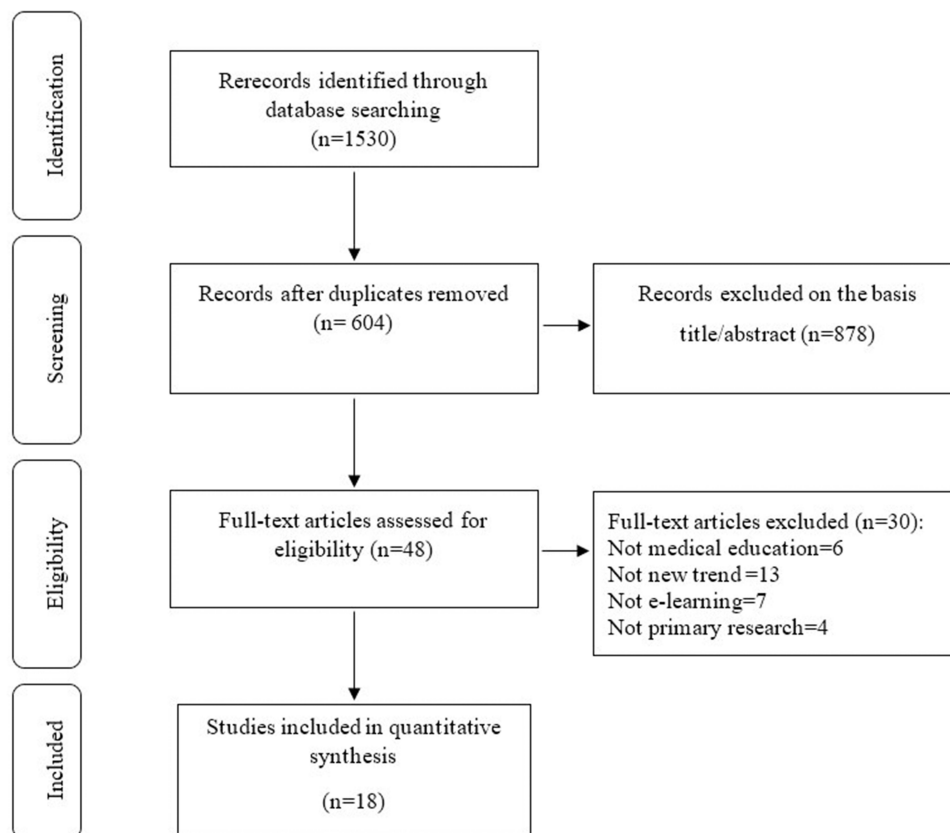


Figure 1 PRISMA flow diagram of the included studies in this review.

**Table 1** Characteristics of Included Studies

Authors (year)	Country	Discipline	Study Design	Tech. Type	Tech. use	Reference
RG Votaw, BB Farquhar (1978)	USA	NA	NA	Computer; Computer simulation of patients and physical examinations; Evaluation of Clinical Competence of Physicians	Simulation of patient-physician interaction; participation in Continuing Medical Education (CME); Use of simulation to assess clinical competence	[15]
DR Masys (1998)	USA	Medicine and Health Care	Review article	Basic text-based tutorials and computer-based assessments based on CPU	3D and interactive visualization of body structures	[16]
ID Căruntu (2000)	România	Histology	Review article	www page	Web HTML histology	[17]
SE Farrell et al (2009)	NA	Emergency Medicine	Review article	Simulation; Online virtual emergency room; CD-ROM-based tutorial virtual reality	-Effect of a CD-ROM-based educational intervention on residents' knowledge and adherence to deep vein thrombosis prevention guidelines -Simulation-based medical education for medical students -Design, development, and evaluation of a virtual emergency department for trauma team training	[18]
RM Satava (2010)	USA	Surgery	Review article	Simulation	- Use across fields, including virtual cadavers, endovascular procedure simulations, and manikins for technical skills like airway management and anesthesia induction. -Management of training and clinical practice	[19]
JR Ratka (2010)	France	Nurse	Qualitative	Web 2.0	Web-based training	[20]
I Masic (2013)	NA	NA	Review article	Application of computers in healthcare services - Classification of computers and their application in medical sciences - Application of computer technology in all medical fields - Medical care, medical education, and medical research	-Application of computer technology in all fields of medicine - Medical care, medical education, and medical research and its evolution	[21]
K Walsh (2014)	UK	NA	Letter	E-learning; simulation	Use of technologies such as e-learning and simulation in postgraduate	[22]
RM Alkoudmani, RM Elkalmi (2015)	Malaysia	Pharmacology	Review article	Web 2.0	Pharmacology training	[23]

(Continued)

**Table 1** (Continued).

Authors (year)	Country	Discipline	Study Design	Tech. Type	Tech. use	Reference
S Kuhn et al (2017)	Germany	NA	NA	Types of educational media - emerging trends in education	Using new technologies such as simulation, virtual patient, and mobile learning	[24]
VK Chimurkar et al (2017)	India	NA	Original article	3D animation through the KIOSK e-learning tool	Learning anatomy	[25]
Y Yan & H Chen (2021)	China	NA	Review article	Blended learning environment	Digital health education	[26]
LA Hampson (2021)	USA	Urology	Review article	Social media, YouTube, Website	Online education in urology	[27]
A Ghassan (2021)	Pakistan	Dentistry	Review article	Simultaneous and blended e-learning simulation Augmented Reality Electronic OSCE	NA	[28]
U Pinar et al (2021)	UK	Urology	Original article	Google Forms, Videos, workshops or masterclasses, and podcasts	To assess young urologists' education and preferences in the field of oncurology	[29]
JC Park et al (2021)	Korea	Dentistry	Review article	Computer-assisted learning, Virtual patients, Augmented reality, 3D printing, simulation, Google Forms, YouTube	Student-centered active learning and the development of clinical competency	[30]
LC Pien et al (2022)	USA	Immunology	Review article	Virtual simulations	Using a virtual simulation scenario for parents of children with asthma to mimic the home environment and assess parents' ability to manage asthma exacerbations	[31]
Mu-Hsiung Chen (2023)	Taiwan	Dentistry	Original article	Online course	Using online courses for dentist continuing education (DCE) course	[32]

COVID-19 pandemic's impact on educational practice and the accelerated adoption of online technologies. Additional contributions appeared in 2017 and 2010, with two articles each, while 1978, 1998, 2000, 2009, 2013, 2014, 2015, 2022, 2023, and 2024 each had a single publication.

Review articles comprised the majority ( $n = 11$ ), followed by six empirical research articles and one letter to the editor, indicating a predominance of conceptual and synthesis-based scholarship in this area. Moreover, six studies were characterized as either quantitative or qualitative research.

The geographic distribution of the included studies was diverse, reflecting the global relevance of educational technology. The United States accounted for six publications, followed by Taiwan, Malaysia, China, France, Germany, England, Korea, Romania, India, and Pakistan, each contributing one article. Two studies did not specify their country of origin. This spread underscores the international nature of research dedicated to technology integration in medical education.

**Table 2** Technological Trends in Medical Education During the Period 1978–2024

Year	Number	Examples of Technological Trends in Medical Education
1978	1	<ul style="list-style-type: none"> <li>● Computer-Based Medical Education (CBE)</li> <li>● Simulation of the Patient-Physician Encounter System (CPPES)</li> <li>● Use of simulations to assess clinical competence (SACC)</li> <li>● Computer-Based Educational Materials (CBEM)</li> </ul>
1998	1	<ul style="list-style-type: none"> <li>● Computer-Based Education and its possibilities for medical education</li> <li>● Predicting the achievement of immersive physical environments in the future</li> <li>● Predicting the use of wireless communication services for accessing clinical data</li> <li>● Digital storage</li> <li>● Medical informatics and its application in healthcare, research, and training</li> <li>● Changes in the doctor-patient communication process due to IT expansion (eg, home care, self-diagnosis and self-care, telemedicine, asynchronous and message-based communication)</li> <li>● Personalizing healthcare and education services in the future</li> <li>● Access to clinical data</li> </ul>
2099	1	<ul style="list-style-type: none"> <li>● Simulation in the Emergency Medicine Training Program</li> <li>● Online virtual emergency, web-based training</li> <li>● Self-direction as one of the learning tools</li> <li>● Virtual reality for teamwork training</li> </ul>
2010	3	<ul style="list-style-type: none"> <li>● Use of physical models and animal parts (teaching basic skills and specific tasks)</li> <li>● Use of Mannequins: Airway Training, Anesthesia Skills and Team Training</li> <li>● Computer-based interactive programs (simulations based on virtual reality-augmented reality)</li> <li>● Videoscopic reality simulations (for teaching laparoscopic surgery)</li> <li>● Web 2.0 tools, web-based learning management system, online authoring tool</li> </ul>
2013	1	<ul style="list-style-type: none"> <li>● Telemedicine, Distance Learning, Web-Based Education.</li> <li>● All healthcare professionals use terminal and personal computers in telemedicine, distance learning (DL) (web-based medical education), application of ICT, medical robotics, genomics, etc.</li> <li>● We facilitate medical services with unique medical informatics capabilities (diagnosis, care, and treatment).</li> <li>● The computer is the most critical data processing tool (especially in medicine and healthcare).</li> </ul>
2014	1	<ul style="list-style-type: none"> <li>● Expected use of technology-enhanced learning, e-learning, and simulation in the future</li> </ul>
2015	1	<ul style="list-style-type: none"> <li>● Expected use of technology-enhanced learning, e-learning, and simulation in the future</li> <li>● Web-based learning and Web 2.0 tools</li> <li>● Use of the Moodle learning management system</li> <li>● Facebook as an effective social medium in medical training</li> <li>● A podcast is a suitable tool for educational purposes</li> <li>● Online presentations (synchronous approach and asynchronous approach with simultaneous recording and review)</li> <li>● Blended learning</li> </ul>
2017	2	<ul style="list-style-type: none"> <li>● E-learning in various forms: Massive Open Online Courses (MOOCs) as additional training – inverted classroom method</li> <li>● Classic digital and communication technologies such as PDF or PowerPoint files and email</li> <li>● Mobile, interactive, and personalized formats in the digital education and learning sector (serious games and virtual patients)</li> <li>● Communication tools and classic digital media (email, PDF or PowerPoint files, Subject-specific databases, and e-books/e-journals)</li> <li>● Social communication tools (blog, chat, forum, microblogging, social networks: Facebook, Twitter and WhatsApp),</li> <li>● Electronic examination system (e-assessment, e-examination, E-OSCE, AMBOSS platform)</li> <li>● Teaching materials with audio/video formats, teaching videos (recorded lectures, screencasts – high quality and studio videos)</li> <li>● Interactive tools and formats (such as educational games/serious games)</li> <li>● Subject-specific interactive tools (eg, simulation of virtual patients/clinics/laboratories)</li> <li>● Online office tools, simulations, web conferences, wikis</li> <li>● Virtual patients via famous systems, eg, Web-SP, CASES, In Media, and Open Labyrinth</li> <li>● Learning management systems Moodle and ILIAS</li> <li>● Blended learning</li> <li>● 3D animated video display</li> </ul>
2021	5	<ul style="list-style-type: none"> <li>● Using Google Forms for Virtual Assessments</li> <li>● Video conference, workshop or masterclass, podcast (as a preferred educational medium)</li> <li>● Blended learning</li> <li>● Augmented reality</li> <li>● Social media such as YouTube</li> <li>● Simulation of surgical training (robotics, endoscopy, and laparoscopy)</li> <li>● Computer-based education</li> <li>● Virtual patients</li> <li>● Simulation of human patients and virtual reality to assess students' competence</li> </ul>

(Continued)

**Table 2** (Continued).

Year	Number	Examples of Technological Trends in Medical Education
2022	1	<ul style="list-style-type: none"> <li>● Virtual training and various e-learning approaches</li> <li>● Blended learning</li> <li>● Medical training based on simulation</li> <li>● Digital radiography</li> <li>● Reverse mentoring</li> </ul>
2023	1	<ul style="list-style-type: none"> <li>● Online Education</li> <li>● Dental radiography</li> </ul>

Technological trends were examined across a range of medical science disciplines. The majority were conducted in medical schools, with specific focus areas including urology (2 studies), surgery, emergency medicine, immunology, histology, pharmacology, nursing, dentistry (3 studies), and health centres (1 study). Six studies did not report a specific field of application. Table 1 provides an overview of the characteristics of the studies included in this review.

## Description of Various Technologies and Technological Trends in Medical Education

Data analysis of the reviewed articles revealed the utilization of a wide array of educational technologies. The reviewed articles were categorized into three primary technology groups:

1. **Classic Educational Technologies:** Traditional one-way instructional media, including PowerPoint presentations, films, books, and pamphlets<sup>25</sup>
2. **Digital and Interactive Educational Technologies:** Interactive platforms promoting learner engagement, such as serious games, simulations, virtual patients, workshops, and podcasts.<sup>15,16,18,20,22,23,25,30</sup>
3. **Supporting and Auxiliary Educational Technologies:** Tools facilitating learning and assessment, including learning management systems, video conferencing programs, computers, 3D animations, websites, computer-assisted learning, and augmented reality.<sup>20,23,25,32</sup> Table 2 summarises the technological trends between 1978 and 2024.

Table 2 demonstrates substantial variability in the educational technologies cited throughout the review period, ranging from early computer-based instruction to modern technologies such as simulation, virtual reality, and academic applications of social media. Table 3 lists the predominant technologies and trends identified during this timeframe.

As detailed in Table 3, e-learning and simulation technologies were the most frequently cited tools, appearing approximately eight times each with multiple examples, indicating their central and sustained role in the field since the late 1970s. While computer-based learning emerged as a persistent trend, more recent years have seen a prominent rise in online teaching platforms, blended learning, and digital assessment tools.

**Table 3** Findings on Technology Types and Common Trends Over the Period 1978–2024

Technology and Examples	Frequency	Period	References
<b>Computer-based education/learning</b> (computer-assisted Web 2.0 tools)	7	1978–2021	[15,16,18,19,21,23,30]
<b>E-learning</b> (eg, distance learning, online learning, web-based learning, video conference-online courses)	8	2013–2024	[22,23,25,27,30,32]
<b>Blended learning</b> and aspects of the blended learning environment	5	2017–2022	[23,24,26,28,31]
<b>Simulation</b> (eg, molasses, mannequins, animal corpses), human patient simulation, computer-aided simulation of clinical encounters, simulation based on virtual reality and 3D images, patient video simulation, emergency medicine training program simulation, videoscopic reality simulations, surgical training simulation (eg, Robotics, Endoscopy, and Laparoscopy)	8	1997–2022	[18,19,24,25,28,30,31]

(Continued)

**Table 3** (Continued).

Technology and Examples	Frequency	Period	References
<b>E-Assessment</b> (online assessment, online questions, e-OSCE, e-portfolio, assessment in Google Forms)	6	2010–2022	[18,19,22,23,30,31]
<b>Learning tools and platforms</b> (eg, Moodle LMS, Elias, Zoom, Skype, content hosting websites, online repositories and hypertext, online platforms for the distribution and evaluation of teaching materials)	5	2015–2021	[23,24,26–28]
<b>Learning tools and social media</b> (eg, podcast, master class, video, screencast, video/audio training formats, video-based learning, multimedia training packages, Facebook, Twitter, WhatsApp, YouTube, etc).	5	2015–2021	[23,24,26,27,29,30]

A considerable number of studies have addressed e-learning modalities, including distance learning and online service delivery, under various labels.<sup>15,20,21,28,30</sup> Wireless clinical data access,<sup>23</sup> synchronous/asynchronous/blended formats,<sup>28,32</sup> and inter-professional collaboration<sup>27,31</sup> were also highlighted. The progression toward mobile learning, personalized delivery, and technology-enhanced learning (TEL) further illustrates the field's shift toward flexible instructional models.<sup>22,24</sup>

Other technologies included webinars, virtual conference broadcasting,<sup>23,27</sup> MOOCs,<sup>24</sup> and diverse blended learning strategies.<sup>23,24,26,28</sup> Concerning assessment, studies referred to online formative testing,<sup>23,28</sup> E-OSCE formats, e-portfolios, discussion-forum evaluations, and electronic testing systems,<sup>22,28,31</sup> as well as Google Forms and WebQuest tools.<sup>20,30</sup>

A variety of LMS platforms (eg, Moodle, ILIAS),<sup>23,24,26,28</sup> video conferencing applications (Zoom, Skype, Google Meet),<sup>24,28</sup> educational repositories, and hypertext systems were also identified.<sup>15,28</sup> Technologies for collaborative learning through social media (Facebook, YouTube),<sup>24,26,29</sup> podcasts,<sup>23,29</sup> and interactive multimedia tools<sup>18,24,28</sup> were emphasized.

Simulation technologies included both traditional formats (moulages, manikins, cadavers) used to train airway and anesthesia skills<sup>19</sup> and advanced, high-fidelity simulations that replicate clinical scenarios.<sup>18,30</sup> Contemporary innovations such as CASE systems, virtual and augmented reality simulations, and video-assisted reality simulators in laparoscopic surgery were frequently documented.<sup>19,25,28,30,31</sup> Standardized and virtual patients also represented important instructional and evaluation tools.<sup>24,31</sup>

## The Utilization and Description of Mentioned Technologies

The selected articles described the practical applications of each technology in line with the studied trend. Major technological applications are detailed in [Supplementary Table 1](#), illustrating diverse implementations across the review period (1978–2024).

## Limitations Raised in the Research Reviewed

Several methodological limitations were noted, including restricted database access,<sup>26</sup> single-language publications,<sup>31</sup> geographically narrow sampling,<sup>24</sup> lack of empirical validation,<sup>22</sup> and low response rates.<sup>29</sup> These constraints may limit the generalizability and comprehensiveness of reported findings.

## Strengths of New Technologies From a Research Perspective

Emerging medical technologies have strengthened diagnostic accuracy and clinical decision-making.<sup>16</sup> In disciplines such as anatomy, interactive 3D visualizations provide a superior learning experience compared to traditional 2D modalities, while simulation-based education enhances patient safety and procedural competence.<sup>18</sup> Web-based technologies expand accessibility, flexibility, and learner autonomy, thereby supporting key competencies required in contemporary medical education.<sup>23,33,34</sup>

**Table 4** Topics/Trends Predicted by Article Authors Over the Period 1978–2024

Status of implementation by 2024	Expected Topic/trend	Year of Publication	The Author of the Article
Reached <sup>35–37</sup>	The creation of advanced local area networks connected to the Internet and accessible via microcomputer workstations will accelerate scholarly communication between faculty and trainees and serve as a model for future professional interactions.	1988	Daniel Massis
Reached <sup>38</sup>	Achieving the best pharmaceutical care for patients soon using Web 2.0 tools, including online EdTech websites and social media	2015	Alkoudmani, Ramez M
Reached <sup>39,40</sup>	The use of simulation technology by professional associations	2010	Richard Sawata
Relatively successful <sup>41–44</sup>	Virtual education as an effective way to train assistants will continue not only during COVID-19 but also in the future.	2021	Hampson, Lindsey
UnknownNo study found	Calls for a national video-based curriculum for learning assistants		
Reached <sup>45–47</sup>	Digital doctor-patient communication, “smart devices” and apps, telemedicine, “virtual/augmented reality”, and “big data” will be part of the digital medical curriculum.	2017	Sebastian Cohen, Susan Frankhauser, and Daniel Tulk
Reached <sup>48</sup>	Compilation of a comprehensive training program to familiarize yourself with medical informatics and influential trends in the treatment and healthcare process	2013	Izet Masich
Reached <sup>49</sup>	With the advancement of technology, computers and other electronic devices will play a very important and important role in the medical profession in the future.		
Reached <sup>50</sup>	Presenting the model of integrating new technologies into the curriculum of specialized clinical areas of the medical sciences		
No study found	Develop and test innovative simulation scenarios and technologies for the education and assessment of allergies and immunology, particularly for rare or complex cases.	2022	Lily C. Payne-Alice Hoyt-Judith C. French

## Weaknesses of New Technologies From a Research Perspective

The successful implementation of technology-enhanced learning depends on robust infrastructure and ICT access, which may not be uniformly available.<sup>23</sup> Technical barriers, decreased motivation due to limited social interaction, and insufficient educator training may compromise learning outcomes.<sup>28,34</sup> Specifically, a notable gap exists in the empirical validation of newer tools like Web 2.0 technologies, where studies often focus on implementation rather than a rigorous assessment of learning outcomes.<sup>31</sup>

## Predicted Trends About the Future of Technology in the Research Studied

Multiple studies provided forward-looking perspectives on emerging technologies and anticipated developments across the review period. Table 4 summarizes key projected trends and evaluates their degree of realisation between 1978 and 2024.

## Discussion

This systematic review aimed to 1) identify and categorize influential educational technologies, 2) analyze their reported effects on learning outcomes and competency development, and 3) synthesize the recurring challenges and strengths associated with their integration. The following discussion interprets our findings in relation to these objectives, organized around six major thematic trends that emerged from the analysis over the review period. It highlights a paradigm shift in the utilization of technology for medical education, a transformation that was particularly accelerated

during and after the COVID-19 pandemic.<sup>19</sup> This period reinforced the importance of adaptable instructional models and catalyzed the widespread adoption of web-based instructional approaches that had been developing for years. The rise of computer technology and internet-based applications has expanded the potential of e-learning and catalyzed the transformation of medical training worldwide. However, concerns remain about the over-reliance on simulation technologies, which have evolved from cadaver- and mannequin-based models to computer-based and augmented reality simulations.<sup>32,41,51,52</sup> The following six thematic areas represent major trends identified in this review.

## Computer-Assisted Instruction (CAI) Programs

The integration of computers and educational software is significantly reshaping medical curricula. CAI programs enable learners to study at their own pace, encounter rare clinical scenarios, and benefit from enhanced faculty–student interaction.<sup>15,16</sup> Fluency with ICT terminology, clinical databases, and decision-support systems has consequently become essential for educators and medical professionals. Computer-based learning promotes wider distribution of educational material without proportionally increasing staffing needs and facilitates rapid curricular revisions aligned with evolving medical knowledge. These developments support prior research, indicating that continuous advancement in information and communication technology (ICT) will remain a defining feature of future medical education.<sup>21,26</sup>

## Web 2.0 Tools and Learner-Centric Education

The evolution of web-based education has paralleled the growing interest in Web 2.0 tools that support interactive, learner-centered pedagogies. This review found that platforms such as social media and online educational environments have had notable impacts, particularly among millennial learners in pharmacy and medicine.<sup>15,16,18</sup> Despite proven benefits in confidence building and knowledge retention, persistent barriers—including high communication costs, weak ICT infrastructure, linguistic challenges, and limited faculty training in developing countries—continue to impede widespread adoption of e-learning. Nonetheless, the ongoing refinement of Web 2.0 technologies holds promise for creating engaging, customizable learning environments tailored to the digital generation.<sup>19,21,23,30</sup>

## Blended Learning and Collaborative Education

Blended learning has emerged as a dominant educational strategy, integrating online technologies with traditional face-to-face instruction to support flexible, collaborative learning. Evidence indicates that blended approaches enhance learner satisfaction, interaction, and critical thinking, while flipped classroom formats further improve motivation and academic performance. The pandemic did not create new trends but rather markedly accelerated the adoption of pre-existing strategies, such as blended and virtual assessment approaches, especially in dental and clinical education.<sup>23,24,26,28,31</sup>

## Enriching the Educational Landscape with Digital Tools

Digital tools have enriched medical education by providing supplementary, learner-friendly resources.<sup>53</sup> The reviewed studies highlighted diverse modalities such as social media, audiovisual technologies, educational podcasts, and interactive multimedia formats. Utilization of 3D animation and CD-ROM-based learning modules has demonstrated superior outcomes compared to conventional instructional techniques. The pandemic further catalyzed the incorporation of platforms such as YouTube, supporting on-demand, globally accessible content and reinforcing the shift toward scalable, technology-enabled learning.<sup>23,24,26,27,29,30</sup>

## Virtual Learning Environments (VLEs)

The expansion of online education has driven widespread adoption of learning management systems and virtual platforms.<sup>54,55</sup> These support remote teaching, learner tracking, and faculty–student interaction, enhancing access in undergraduate and postgraduate programs.<sup>56</sup> Examples such as multicenter online training initiatives in urology facilitate national and international collaboration, with evidence suggesting improved knowledge assessment scores among learners participating in virtual lecture series. Consequently, VLEs represent a critical infrastructure for contemporary medical education delivery.<sup>13,18,29</sup>

## Simulation-Based Medical Education (SBME)

Simulation-based education continues to evolve as a foundation of competency-based clinical training. Modern SBME integrates high-fidelity manikins, virtual reality (VR),<sup>57</sup> augmented reality (AR), and artificial intelligence to provide immersive, feedback-rich experiences. These environments allow learners to practice critical procedures safely, reflecting a broader shift toward outcome-driven, performance-based assessment frameworks.<sup>58–61</sup> Simulation thus supports mastery of essential clinical competencies and aligns with the professional expectations of next-generation healthcare practitioners.<sup>18,19,24,25,28,30,31</sup>

## Implications for Practice

These findings underscore the need for strategic, evidence-based technology integration in medical education. Institutions should adopt flexible instructional designs, including blended and cooperative e-learning models, and implement continuous evaluation mechanisms to assess their educational impact. To guide policymakers and curriculum designers, investments should focus on simulation technology, virtual patients, and informatics training to prepare learners for digitally mediated clinical practice. Furthermore, expanding research collaborations, increasing sample diversity, and supporting multilingual and multicenter studies can enhance generalizability and inform policy-level decisions.

## Limitations

Although this systematic review incorporated comprehensive search strategies, potential limitations include publication bias, exclusion of non-indexed studies, and language restrictions. Additionally, rapid technological evolution means new studies may emerge that further contextualize or expand the current findings. While this review provides a comprehensive longitudinal analysis of major technological trends, the search strategy was designed around broad pedagogical concepts (eg, “e-learning”, “simulation”) to ensure consistency across a 46-year period. Consequently, it may not have fully captured the most recent and rapidly emerging body of literature specifically focused on artificial intelligence (AI), large language models, and generative AI, which have gained prominence predominantly in the latter part of our review window. This represents a limitation and a compelling avenue for future research; a dedicated systematic review focusing exclusively on the trajectory, implementation, and impact of AI in medical education is strongly recommended to build upon the historical context provided by this study.

## Conclusion

This systematic review mapped five decades of technological integration in medical education, establishing a clear evolution from traditional pedagogy to dynamic, technology-enhanced learning. Our analysis, synthesizing findings from 18 studies, identifies simulation-based learning and blended learning as the most substantiated and impactful trends. The evidence consistently indicates that simulation robustly develops clinical and procedural skills,<sup>18,19,30</sup> while blended learning effectively fosters flexible, engaging, and critical learning environments.<sup>23,26,28</sup>

These findings mandate a strategic pivot in educational policy. We recommend sustained institutional investment in simulation and blended learning design, supported by cross-institutional consortia to mitigate costs and mandatory faculty development to ensure pedagogical efficacy. Future efforts must build upon this evidence-based historical analysis, with a critical next step being a dedicated review of artificial intelligence to guide its integration as deliberately as the foundational technologies documented here.

## Generative Artificial Intelligence

During manuscript preparation, we used DeepSeek (V3) solely to improve language clarity and readability. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the published article.

## Abbreviations

PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; OSCE, Objective Structured Clinical Examination; 3D, Three Dimensions; 2D, Two Dimensions; ICT, Information and Communication Technology; CAI, Computer-Assisted Instruction; VLE, Virtual Learning Environments; SBME, Simulation-Based Medical Education; VR, Virtual Reality.

## Data Sharing Statement

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. All relevant data are included within the manuscript and its [supplementary materials](#).

## Ethics Approval and Consent to Participate

This systematic review did not require ethical approval as it involved analyzing published studies and did not include direct interaction with human participants. Therefore, no ethical approval code was obtained. All studies included in this review were conducted following ethical standards.

As this study is a systematic review synthesizing data from previously published studies, it did not require ethical approval from an institutional review board. No direct interaction with human or animal subjects occurred as part of this research.

## Consent for Publication

All authors have consented to the publication of this manuscript.

## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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