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Enablers and challenges of integrating digital health into medical education curricula: a scoping review

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Abstract

Background The global strategy for digital health advocates digital health literacy in formal education and training curricula for all health professionals. However, little is known about the enablers and challenges of integrating digital health into medical training curricula.

Methods Guided by Arksey and O'Malley's scoping review methodology, we searched the PubMed, Google Scholar, and ScienceDirect scholarly databases for peer-reviewed articles published between 2014 and 2024. Data extraction was guided by the consolidated framework for implementation research.

Results Thirty studies met the inclusion criteria and were analyzed. The enablers identified include the need for healthcare digitalization, reshaping the future daily work of healthcare professionals, decreasing students' doubts about digital health and increasing the quality of patients' care. On the other hand, a lack of infrastructure and educational materials, the dense nature of the existing curriculum, and bureaucratic tendencies were identified as challenges. The provision of consolidated funds and the establishment of dedicated digital health infrastructure, starting with elective and audited modular approaches, raising awareness, and educating stakeholders, emerged as implementation strategies for mitigating these challenges.

Conclusion Global progress toward integrating digital health literacy in formal medical training curricula remains slow. There is a need for concerted efforts and political commitment to offer guidance and moral and financial support for this integration.

Keywords Digital health, Medical curricula, Integration, Enablers, Challenges

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Contributions to the literature

- Despite the need for training institutions to establish and provide lifelong learning opportunities for digital health technologies, medical education remains insufficiently focused on digital health.
- Although several studies have documented the integration of digital health training in medical curricula, the process cannot be successful unless bottlenecks are identified and mechanisms are put in place to address them.
- This review uses the CFIR and ERIC implementation frameworks to identify enablers, challenges, and potential implementation strategies for addressing the identified challenges.
- Concerted efforts and political commitments from governments and international organizations are urgently needed to establish standards, policy frameworks, and guidelines for this integration.

1 Background

In 2020, the World Health Assembly endorsed the global strategy of digital health 2020–2025 aimed at improving and accelerating the development and adoption of appropriate person-centric digital health solutions [1]. In its efforts to strengthen digital health governance among member states, the WHO digital health agenda highlights the need for an integrated strategy for the sustainable adoption of digital health technologies, training institutions to establish and expand digital health literacy life-long learning opportunities and including them in the education and training curricula of all health professionals and allied health workers to prepare them to deploy and use digital health tools in their daily work [1, 2].

Healthcare is increasingly becoming digitalized, offering promise for innovative and improved-quality care [3]. However, the lack of knowledge and skills to use digital health technologies, negative attitudes, technology anxiety, and skepticism among healthcare workers inhibit adoption and implementation in clinical settings [4–8]. Intentional training and educational programs for health care workers who play a critical role in the implementation of digital technologies must be prioritized for training if better implementation outcomes are to be realized [9, 10]. There is a need for mechanisms to increase the capacity of students/future clinicians in the practical use of these technologies as early as possible by integrating digital health into their curriculum to churn digitally competent future medical workers [11, 12].

The introduction of digital health-specific postgraduate programs aimed at producing graduates with skills and competencies in the application of ICT to improve health practice has been in place for decades. Although this has reshaped digital health knowledge among the few who undertake those programs, a large portion of students who do not take health informatics as a course at the postgraduate level are left with an inadequate understanding of digital health and a lack of preparedness to use it [13]. Therefore, despite the availability of these postgraduate digital health courses, opportunities remain skewed toward those with prior qualifications, understanding, and interest [14].

Digital health remains insufficiently represented in medical education, although it is projected to influence the everyday work of physicians in the next 5 years [12]. Its

integration in medical training globally is still in its infancy, but this is understandable given that efforts toward digitizing health care are gaining momentum recently. For example, in Germany in 2019, the deans of 25 European medical schools agreed to rapidly implement digital health education in their medical schools' curricula [15]. Since then, many studies have explored the integration of digital health teaching in medical curricula [5, 16–19] in Europe. A commentary by Aungst and Patel has shown how there is a lack of formal integration of digital health in the medical curriculum of several institutions in the U.S. The majority of these offer certificates in digital health-related courses for those with an interest in the digital health field while leaving out the remaining students who would have benefited from integrating their knowledge with digital health [20]. Another review by Tudor Car and colleagues documented digital health topics related to courses for medical students, curriculum design, assessment, and evaluation, and challenges related to course development [21]. Despite this progress, uptake is not guaranteed [22] if contextual barriers are not systematically identified and if enablers are leveraged to facilitate increased uptake. This can occur through the implementation science lens, which involves identifying barriers and enablers involved in the uptake of interventions across multiple contextual levels while developing potential strategies for addressing the identified barriers and leveraging the enablers for increased intervention uptake [22]. There is an evident dearth of literature that utilizes implementation science approaches to identify enablers and challenges in integrating digital health into medical education curricula. Given that many institutions and nations are gearing up for the WHO 2020–2025 digital health agenda, it is paramount to understand challenges that might hinder integration and enablers to leverage for better outcomes. In this review, we use the consolidated framework for implementation research (CFIR) framework [23] to summarize published evidence regarding enablers and challenges to the integration of digital health in medical training curricula from the literature and the Expert Recommendations for Implementing Change (ERIC) [24] to inform policymakers on potential implementation strategies for successful integration.

2 Methodology

2.1 Theoretical framework

The lack of theoretical frameworks for conducting and performing implementation research hinders the generalizability of the study findings [25]. To facilitate generalizability, several implementation frameworks have been proposed, including the consolidated framework for implementation research (CFIR), which was developed by Damschroder and colleagues to provide a systematic understanding of the constructs that influence the implementation of interventions [23]. The framework provides a systematic assessment of barriers and facilitators through its five main domains, namely, (i) intervention characteristics, which is concerned with the new strategy or program being implemented; (ii) the outer setting, which is concerned with the external features from the community, that can influence implementation; (iii) the inner setting, which is concerned with the features (political, social, physical) of an organization in which the implementation process is effected; (iv) the individual characteristics domain, which is concerned with the characteristics and roles of individuals involved in the intervention or the process of implementation; and (v) the implementation process, which involves a set of activities aimed at achieving individual- and organizational-level use of the intervention as

designed. CFIR has a track record of facilitating the identification and addressing of contextual factors that may facilitate or hinder the practicability, functionality, adaptability, adaptability, and scalability of well-intended interventions [26] and has been used in the identification of barriers and motivators for private hospitals' engagement in TB care [27]. Therefore, utilizing CFIR to explore enablers and challenges in integrating digital health modules into medical curricula is paramount to guide future rethinking of integration approaches to similar interventions. To identify implementation strategies for the identified challenges, we used the expert recommendations for implementing change (ERIC), a compilation of 73 implementation strategies that were developed by a panel of experts in implementation science and practice to foster action-oriented research and overcome identified challenges [24]. The combination of these two frameworks, CFIR and ERIC has been used in Australia to help identify theoretically informed matching strategies to address barriers identified by the CFIR [28, 29], thus making it the most suitable framework for this work compared to other models that we deemed inadequate to categorize the enablers and challenges while on the other hand suggesting theoretically informed matching strategies.

2.2 Scoping review methodology

The findings of this review were reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) extension for the scoping reviews checklist [30]. The presentation of review findings was guided by the Arksey and O'Malley scoping review methodology [31]. This methodology allows the inclusion of diverse study types and outlines six main steps to be followed while conducting a scoping review, namely, (i) identifying the research question, (ii) identifying relevant studies, (iii) selecting studies, (iv) charting data, (v) collating, summarizing and reporting results, and (vi) consulting (this step was not considered for this review). We purposively searched, identified, screened, and analyzed relevant studies that discussed the integration of digital health modules into the medical curriculum. There is no published protocol for this review.

2.3 Identification of the research question

This study was guided by two main research questions: *(i) what are the enablers for integrating digital health training in medical curricula, and (ii) what challenges are encountered during the integration of digital health training in medical curricula?* Therefore, the articles identified by the reviewers intended to address the questions above.

2.4 Identification of relevant studies

We conducted a comprehensive review of the relevant literature in August 2024 to identify published studies that captured the current state of the art regarding the enablers and challenges of integrating digital health training in medical curricula globally for inclusion. To identify these relevant studies, the Google Scholar, PubMed, and ScienceDirect bibliographic databases were used because of their high indexing capabilities for peer-reviewed articles. The authors reviewed articles published between 1 st January 2014 and 31 st August 2024 to understand the most recent literature about existing enablers and challenges of digital health training integration in medical curricula. A combination of the following key search terms to denote 'digital health training',

'challenges', 'enablers', and 'Medical Curriculum' was used in the bibliographical databases to identify the relevant articles.

Additionally, the bibliography/reference lists of the identified articles were also screened and reviewed for potential additional relevant studies. EndNote X7 (Thomson Reuters, Philadelphia, PA, USA) was used to manage and organize the search results obtained and to facilitate independent assessment among authors for inclusion on the basis of title, abstract, and full text.

2.5 Study selection

Studies were included if they were (1) peer reviewed, (2) full research papers available, (3) clearly described enablers and/or challenges of integrating digital health training in medical curricula or the enablers and challenges discussed in the methods section, (4) published between 1 st January 2014 and 31 st August 2024, or (5) available and published in the English language. Criteria (1) and (2) were considered to ensure the reporting of original research and high-quality work. Criteria (3) was included to ensure that the paper reported digital health training integration in medical curricula. Our definition of digital health training in medical curricular enablers included advantages, benefits, facilitating factors, and motivators for integrating digital health training into curricula, while we defined challenges as difficulties, barriers, gaps, and problems encountered during the integration of digital health training in medical curricula. Criteria 4 was considered because in 2014, digital health interventions were more pronounced; therefore, the inclusion of research papers published before 2014 would imply the reporting of findings that were not recent regarding digital health training integration in medical training curricula. Studies were excluded if they did not report enablers and/or challenges related to digital health training integration in medical curricula or if they were carried out before 2014 and if they were not relevant to the research questions of this review. All the studies were explicitly scrutinized to ensure that they reported enablers and challenges; therefore, we did not include protocols; editorials; letters; position papers; or opinion pieces. We included all the relevant studies irrespective of the study design and geographical location.

2.6 Charting of the data

The authors reviewed titles and abstracts to identify relevant articles for final inclusion. The following characteristics were extracted from the eligible studies: author, study design/method/location, study objective, digital health module, enablers, and challenges. All the extracted data are included in Table 1. All authors reviewed the articles at length for inclusion in the final analysis.

2.7 Collating, summarizing, and reporting results

A series of iterative meetings, reviews, and discussions were held both virtually and physically with all the research team members to assess, analyze, and agree on the articles for final inclusion in this scoping review. The main characteristics of interest are tabulated in Table 1 to highlight the extraction of the parameters of interest from the identified studies. The structuring of the main findings was guided by the CFIR to extract relevant enablers and challenges.

Table 1 Characteristics of the studies included in this review

Author	Study design/method/location	Objective	Course/modality	Enablers	Challenges
1. (Poncette et al., 2020)	A mixed methods study among third year medical students at Charité—Universitätsmedizin Berlin, Germany	To introduce digital health as a curricular module at a German medical school & to identify undergraduate medical competencies in digital health and their suitable teaching methods	Developed an elective 3-week curricular module on digital health for third-year medical students	• Reshaping the future daily work of health care professionals • Prepare medical students for the highly digitized future healthcare system • Need for future clinicians with a high degree of data competence for good clinical decisions based on complex data. • Urgent need for digitalization • Reduce fears and promote enthusiasm for digital technologies.	• Difficulty in convincing doctors to use digital services and apps
2. (Baumgartner et al., 2022)	A cross-sectional study among registered medical students (year one to year six) at all public medical schools in Austria	To provide a comprehensive dataset about self-assessed knowledge, attitude and recommendations concerning the curriculum by Medical students in the area of digital health.	Not specified	• Digitalisation will improve patient safety within the operations theatre • Data protection viewed as an important for medical students' professional career	• Digitalisation seen as a threat, with respect to the patient–physician relationship
3. (Ma et al., 2023)	A cross-sectional survey among Chinese medical students from 467 medical schools	To understand the perception of digital health among Chinese medical students, the current implementation of digital health education in China, and the urgent needs of medical students	Not specified	• Desire to learn more about digital health in medical courses • Positive expectations that digital health will change the future of medicine	

Table 1 (continued)

Author	Study design/method/location	Objective	Course/modality	Enablers	Challenges
4. (Zainal et al., 2023a)	A qualitative study among clinical educators (deans or vice deans of education) from one of the three medical schools in Singapore	To identify current training gaps at the national level in digital competencies needed by students in the formal curricula of all three medical schools in Singapore from the perspectives of clinical educators and institutional leaders	Yong Loo Lin School of Medicine (YLL) at National University of Singapore (NUS) teaches informatics to 3rd year students as part of their clinical research, offers Virtual reality in core curriculum and 3D technology in anatomy. Lee Kong Chian School of Medicine (LKCMedicine) at Nanyang Technological University (NTU) offers digital health as a core module Duke-NUS Medical School (Duke-NUS) teaches medical students broad concepts of innovation and transformational change	• Need for more training in applying the principles of digital technologies • Need to be taught broad principles and concepts of digital health technologies • Need to train medical students in data management, analysis, protection and security.	• Lack of standardization • Lack of exposure to digital technologies • A densely-packed medical curriculum • Lack of collaboration among medical schools due to different mission and friendly competition to produce competent medical graduates • Disconnect between medical school curriculum and clinical practice
5. (Zainal et al., 2023a)	A qualitative investigation with 33 doctors in executive & organizational leadership roles in Singapore	Assess the barriers to the incorporation of Digital Health competencies in the Medical School Curriculum	Not specified	• Need for more evidence on the effectiveness of digital technologies • Need for a strong and integrated IT infrastructure	• Lack of clear policy guidelines for clinical practice • Bureaucratic inertia • Lack of protective mechanisms for experiential learning and experimentation

Table 1 (continued)

Author	Study design/method/location	Objective	Course/modality	Enablers	Challenges
6. (Zainal et al., 2022)	A qualitative investigation among clinical educators and teachers purposively selected from 12 healthcare institutions, three medical schools, one private clinic and the Ministry of Health in Singapore	Explore the views of local clinical educators and teachers towards the need to impart skills in digital technologies to medical students.	Not specified	• Promoting innovation culture • Improving work efficiency	• The rapid pace of technology advances that make it hard to keep up with • Erosion of basic clinical skills • Abandonment of a generalist approach to healthcare • De-personalisation by technology where doctors spend time looking at their devices instead of maintaining eye contact with them
7. (Walpole et al., 2016)	An online survey among Senior academic staff and health informatics educators at all 34 UK medical schools	To provide current data on the state of health informatics education, exploring whether health informatics teaching has been enhanced or updated based on new guidance and materials.	Informatics teaching is integrated with other curricular topics and in other schools, it is delivered in stand-alone sessions, it is most commonly taught in second-year core curriculum (more common in core than optional teaching)	• Need for a centralised IT training to improve the current system of training in each individual healthcare centre	• Limited awareness of, and lack capacity to teach health informatics topics • Limited formal teaching on informatics • Students do not connect to the terminologies in informatics • Trust IT security often makes this problematic
8. (Vossen et al., 2020)	An online survey among under graduate and graduate medical students from the medical school of Maastricht University in the Netherlands	To evaluate whether medical students desire a dedicated eHealth curriculum during their medical studies.	No formal education about eHealth but students would likely encounter eHealth through their medical rotations. The didactic teaching format preferred was lecturers, tutorials and real life scenarios, and remotely following up a real lie patient with the supervision of a doctor	• Positive attitudes towards incorporating eHealth into the medical curriculum.	• Lack of preparedness to take advantage of the technological developments within the medical field • Discrepancy between eHealth-related content in current medical education and the amount of eHealth training that is considered useful by medical students

Table 1 (continued)

Author	Study design/method/location	Objective	Course/modality	Enablers	Challenges
9. (Veikkolainen et al., 2023)	A cross-sectional study at the University of Oulu and Oulu University of Applied Sciences in Finland among medical and nursing students	To describe the attitudes of medical and nursing students towards digital health based on self-evaluation as well as to compare the differences in perceptions between the two student groups.	Not specified	• Positive attitude towards eHealth and health care digitalisation. • Digitalisation would shape future daily work of health care professionals • Refining basic education of health care professionals to prepare students to adopt digital health care processes and technologies. • Positive attitudes towards the deployment of patient-originated information • Perceived use of self-care systems and applications to promote patient engagement and improve their health outcomes	• Relative reservation in their attitudes towards how digitalization will change the roles of health care professionals and patients in the future
10. (Seemann et al., 2023)	A comparative study on knowledge and Attitudes that involved 17 students in winter semester of 2020/2021 ("Digital Health" group) and 17 students of the same educational level who had chosen different elective courses that served as "reference group" in Germany	To assess medical students' gain of knowledge by participation in a teaching module "Digital Health", and to evaluate their attitudes towards digital health and its role in medical education	A 3-week elective "Digital Health" module had been established at Charité – Universitätsmedizin Berlin medical school in winter semester 2019/2020. It comprises of 60 educational units of 45 min. The elective is offered in third year of medical school amongst a variety of other elective classes with different topics	• Digital medicine will reshape the future daily work of health care professionals • Educating future physicians regarding aspects of digital health early and specifically during medical education	• Not sufficiently engrained in the current undergraduate curricula
11. (Sakellari et al., 2024)	A cross-sectional web-based study conducted among university students from one of the Universities located in Attica, Greece	Assess Digital Health Literacy and online information seeking about COVID-19 among university students in Greece.	Not specified	• Need for promotion of digital health literacy among university students	• Difficulties in extracting or accessing information • Trust issues regarding the reliability of information retrieved via online search is reliable or not.

Table 1 (continued)

Author	Study design/method/location	Objective	Course/modality	Enablers	Challenges
12. (Raghunathan et al., 2023)	A descriptive, cross-sectional study among pre-registration nursing students in Australia	Explore undergraduate nursing students' self-perceptions of informatics competence, set within a larger research project	Not specified	• Foundational information and communication technology skills	• Informatics not taught formally in the curriculum • Limited exposure to important simulated informatics tools in preparation for practice • sub-optimal preparedness for digital health
13. (Farooq et al., 2024)	A cross-sectional analytical study was conducted at King Edward Medical University, Lahore Pakistan	To assess digital health literacy among medical students	Not specified	• Need to elevate digital health literacy levels of medical students • High degree of proficiency in digital health literacy.	• Difficulties regarding data reliability and determining the relevance of the data
14. Pare et al., 2022	A two-phased survey study at the University of Montreal's medical school in Canada	To explore the factors that influence medical students' intention to integrate dHealth technologies in their practice and analyze the influence of the COVID-19 pandemic on their perceptions and intention	5-year long undergraduate medical curriculum, no formal dHealth education or training is provided to students. Students have access to the EDUlib online training platform which offers educational content on a variety of subjects including health and information technologies Workshops on mobile health and EMR systems are mandatory for students in their clerkship	• Intention to integrate digital health as part of their medical degree	• Little occasion to experiment with dHealth technologies

Table 1 (continued)

Author	Study design/method/location	Objective	Course/modality	Enablers	Challenges
15. (Park et al., 2022)	An online survey and Delphi study 60 nursing schools to analyze the current status of nursing informatics education; and second, a two-round Delphi survey with 15 experts in South Korea	To explore the current status of nursing informatics education in South Korea and developed a standardized curriculum for it.	Nursing informatics was most commonly taught in the fourth year (34%), with two credits	• High necessity to introduce Nursing informatics • Necessity to have a standard Nursing informatics curriculum	• Lack of awareness of subject necessity • Lack of educational materials • Difficult to connect digital health to practice • Inconsistent opening of nursing informatics classes • Lack of student understanding • Broad content of nursing informatics
16. (Kröplin et al., 2024)	A pre-post test study among of 20 students that participated in the digital health curriculum at the University of Rostock, Germany	To analyze the objective acquisition of digital competencies through the implementation of a transdisciplinary digital health curriculum as a compulsory elective subject at a German university.	The curriculum "Digital Health - Digitalisation and Digital Transformation of Medicine" was offered for the first time at our university in the winter semester of 2022–2023. Students from all faculties and all semesters of the university were eligible to participate The curriculum contents were taught over a period of 1 semester within the framework of a compulsory elective subject.	• Better overall coverage of the digital health learning objectives among clinical students • Increase in knowledge in digital health competence • Desire to learn AI topic outstanding importance among digital health topics • Promote an innovation-driven teaching and learning environment	• Digital transformation as a continuous process that may not be understood or accepted by those who don't perceive the relevance of digitalization

Table 1 (continued)

Author	Study design/method/location	Objective	Course/modality	Enablers	Challenges
17. (Darnell et al., 2023)	A case conference series FACKS quantitative study at University of Southern California, USA	to assess change in student pharmacists' familiarity, attitudes, comfort, and knowledge (FACK) of digital health after the intentional integration of digital health topics into the case conference series.	University of Southern California School of Pharmacy Proposed incorporating digital health topics into the required case conference series, which runs concurrently with therapeutic courses for a total of 4 semesters. The case conference course is a 2-credit unit, discussion-based course that runs parallel to didactic pharmacotherapy courses concurrently with therapeutic courses for a total of 4 semesters. Each week students are assigned a case and prework to review before the active learning case session.	• Increased student's knowledge in digital competences • Increased students familiarity and comfort with digital health • Perception that digital health is an important aspect of patient care • Willingness to learn more about digital health.	• Students did not receive any introductory lectures on digital health
18. (Alsahali, 2021)	A cross-sectional study among pharmacy interns at Unaizah College of Pharmacy, Qassim University, Saudi Arabia	To assess pharmacy interns' awareness of digital health apps in Saudi Arabia and their views regarding the coverage of digital health in the education of pharmacists	Not specified	• Telehealth could enhance the quality of care, effectively provide patient counselling, and believed it could improve patients 'adherence to therapy. • Need to educate and train pharmacists in the field of digital health. • Positive perceptions and beliefs about the concepts, benefits, and implementation of digital health	• Believed that telehealth could increase their workload. • Digital health requires more mental effort

Table 1 (continued)

Author	Study design/method/location	Objective	Course/modality	Enablers	Challenges
19. (Machleid et al., 2020)	Explanatory mixed methods design among European medical students. European Medical Students' Association (*Association Européenne des Étudiants en Médecine*; EMSA) a nonprofit, nongovernmental organization representing the voice of medical students from over 110 faculties in 30 countries across Europe.	To assess European medical students' perceived knowledge and opinions toward digital health, the status of digital health implementation in medical education, and the students' most pressing needs	Not specified	• A need for more eHealth implementation into medical curriculum • eHealth integration in their curriculum would prepare students for their future working environment, keep education up-to-date, and reduce their doubts about eHealth. • Willingness to learn about eHealth. • Digital health literacy viewed as a job qualification and to maintain physicians' responsibilities	• Lack of digital health-related formats in medical education • Perceived lack of digital health literacy • Lack of digital skills • No eHealth-related courses provided at their faculty at all • High density of learning content in the medical curriculum. • Poor eHealth skills
20. (Lotrean and Sabo, 2023)	A cross-sectional Survey among fifth and sixth year students of the Faculty of Medicine from the Iuliu Hat, ieganu University of Medicine and Pharmacy in Cluj-Napoca, Romania	To assess training, attitudes, and intentions to use digital tools among Romanian medical students.	Not specified	• Need to introduce a formal training in the medical curricula regarding digital health • Positive attitudes towards the use of digital tools • Need for more training in the field of digital health	• Students not convinced about early disease detection, monitoring and self-management
21. Casa et al., 2021	A cross-sectional, multicentre Survey among Italian young medical doctors aged < 35 years in Italy	To assess DH awareness and previous knowledge among young doctors in Italy	Not specified	• Young Italian doctors are more involved in the use of telemedicine tools • High interest, knowledge and involvement in digital health and innovation, that have seen and experienced new technologies in their clinical or research setting	• Low experience in the digital revolution in medicine
22. (Edirippulige et al., 2022)	A mixed methods study among medical students and academic staff members of the Faculty of Medicine at the University of Queensland, Australia	To explore medical students' perceptions and expectations of digital health education and training	The medical curriculum at the University of Queensland did not have a digital health component at the time of the study.	• Students interested in learning about digital health as part of their medical programme. • Growing use of digital technologies within health care • Digital health is going to be part of routine practice • Digital technologies viewed as tools to help patients organise their health	• No prior experience in digital health • Not sure how digital health would benefit them in my future practice

Table 1 (continued)

Author	Study design/method/location	Objective	Course/modality	Enablers	Challenges
23. (Faihs et al., 2022)	A cross-sectional online survey among medical students in the clinical semesters at the Technical University of Munich, Germany	Assess the students' needs and wishes regarding digital health literacy, as an elective course to be established	The medical curriculum at the Technical University of Munich, did not have a digital health component.	• Belief that medicine will be fundamentally changed by new digital opportunities in the next few years • Desire for further education on the topic of digital medicine.	• Lack of preparedness among students for the digital challenges in their future profession • Fear of the digital challenges in the medical profession.
24. (Evbuomwan et al., 2020)	A cross-sectional online survey of 135 students who were studying Human Medicine in Nigeria or overseas	Assess the opinions of medical students on the incorporation of ICT as an academic course into undergraduate medical curriculum.	The medical curriculum at Aminu Musa Habib College of Health Science and Technology, Yauri, Nigeria did not have a digital health component.	• Perceived belief that the future is digital • Enthusiasm about using and/or promoting digital health strategies • Need to integrate digital health in their medical schools' curriculum	• Lack of basic training on ICT despite their high rate of lifetime use of digital health products
25. (Brockes et al., 2017)	Evaluation study of the Clinical Telemedicine/e-Health module integration in the Curriculum among Medical Students at the University of Zurich, Switzerland	To evaluate the 8 years of results and experience in teaching Clinical Telemedicine/e-Health elective among medical students	An elective Clinical Telemedicine/e-Health module was implemented by the Faculty of Medicine of Zurich in 2008. Offers 7 interactive days every semester, which provide students with the opportunity to attend multiple lectures in the mornings from 8:15 am until midday. The students have to deal with two Simulated medical online questions as homework using a Web-based training platform to receive their certification of "Clinical Telemedicine/e-Health."	• Digital health has potential to supplement traditional treatment and consultation • Increased clarity about the need for telemedicine • Increased overall satisfaction and understanding of telemedicine as a supplement in traditional medical consultations increased • Willingness to use telemedicine for chronically ill and elderly patients.	• Lack of proper understanding regarding the aspects of data protection in the digital healthcare system

Table 1 (continued)

Author	Study design/method/location	Objective	Course/modality	Enablers	Challenges
26. Ejaz et 2022	A mixed-methods study of focus groups and surveys with 128 medical students from 48 countries. Participants were students of the national member organisations (NMOs) of the International Federation of Medical Students' Associations (IFMSA).	To provide the first report on the state of artificial intelligence in medical education globally by exploring the perspectives of medical students	Not specified	• Support for incorporating teaching on artificial intelligence into core curricula • Potential of AI to improve access to care in underserved communities in LMICs and to improve the quality of care in remote and rural communities. • Need to learn the basic computer science theory needed to understand AI and coding classes. • Potential of AI to reduce medical error	• Few students had received teaching on artificial intelligence • Raised ethical concerns and should be exercised with cautious optimism • Lack of access to the internet.
27. (Gillissen et al., 2022)	An exploratory sequential mixed-method analysis among medical students from all medical Faculties in Germany	To explore attitudes of 2020 medical students' generation towards various aspects of eHealth technologies with the focus on AI	Not specified	• Simplification of doctor consultations, particularly in sparsely populated areas, possible 24/7 doctor access, and the medical on-the-spot support of paramedics • Potential of digital health to change the way doctors and patients will deal with each other. • Digitization not viewed as a competition for doctors but as an accessory tool to improve their performance, save time, and make their work easier.	• AI viewed more as an encumbrance than as useful assistance • Lack of AI and other digital solutions for patient care in the curriculum • Concerns related to potentially unreliable and non-certified internet sources eventually causing confusion in the patient–doctor relationship especially when the physician disagrees with the patient's medical inquiry • Doubt in the reliability of health apps and their practical usefulness for doctors

Table 1 (continued)

Author	Study design/method/location	Objective	Course/modality	Enablers	Challenges
28. (Sorg et al., 2022)	A descriptive cross-sectional study among medical students from 38 German faculties	To find out the attitude and the degree of preparation of upcoming medical professionals for digital medicine.	Not specified	• The digitalization of medicine and medical teaching has significantly increased because of the pandemic • Digitalization will change the medical profession in the future	• Majority had not had any university courses on digital topics • Lack of preparedness for the technical reality of digitalized medicine. • Fear of losing patient contact because of digitalized medicine • Concerns about incorrect decisions and the consecutive medico-legal aspects of using digital support as part their treatment plans. • Concerns of lack of backup systems backup systems in the event of system failure • Concerns of lack of Infrastructure (necessary software and hardware to use respective tools or platforms in digital medicine
29. (Alfallaj et al., 2022)	A national prospective cross-sectional survey among chairpersons of prosthetic sciences departments of the 27 dental schools in Saudi Arabia	To investigate the status of digital dental technology (DDT) adoption in Saudi Arabian undergraduate dental education.	Not specified	• Need to integrate digital components into Saudi Arabian dental schools' curricula and patient care treatment	• The schools that did not incorporate DDT into their undergraduate curricula due to not being included in the curriculum • Lack of technical expertise • Untrained faculty and staff • High Costs

Table 1 (continued)

Author	Study design/method/location	Objective	Course/modality	Enablers	Challenges
30. (Nitsche et al., 2023)	A quasi-experimental evaluation design among students from Witten/Herdecke University health and business and society Faculties in Germany	To assess student attitudes toward digital medicine topics and conduct self-assessments of their digital competencies before and after the course	Digital Medicine course was delivered digitally using the Adobe Connect meeting software during the summer term of 2020 (ST20). The course took place weekly on Thursdays from 18:00 to 19:30. The students received two credits in the European Credit Transfer and Accumulation System for their participation, which was tracked via login	• Positive view of digitization in healthcare • Open but critical attitude toward digitization in healthcare • They did not feel that digitization posed a threat to their jobs • Produced changes in attitude to believe that digital transformation brings more advantages than disadvantages • Positive development of digital sub-competencies and the feeling of being prepared for the consequences of digitization.	• Ethical concerns

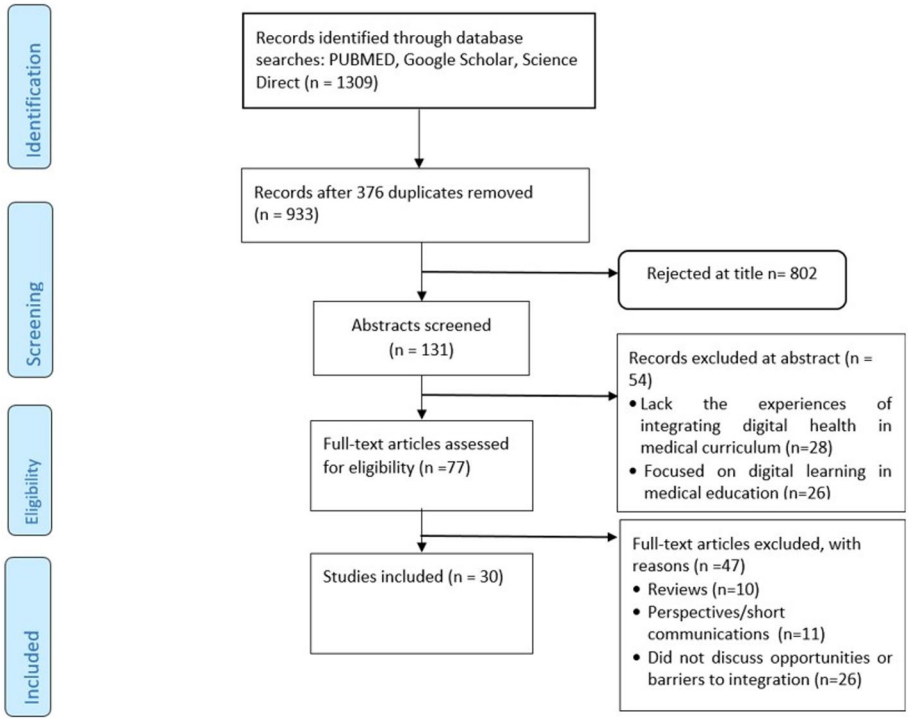


Fig. 1 Flow diagram for the selected studies

3 Results

Our initial database search identified 1309 articles, 376 of which were duplicates, as shown in Fig. 1. Eight hundred two articles were eliminated after screening the titles, and an additional 54 articles were removed from the abstracts. Forty-seven articles were excluded from the full-text review. Therefore, 30 studies were included in the analysis. The majority of the studies were conducted in Europe (60%, 18/30), 27%, 8/30 were conducted in Asia, with only 7%, 2/30 from North America, whereas both Africa and Australia accounted for only 3%, and 1/30, respectively, of the studies, as shown in Table 1.

Of the 39 constructs of the CFIR framework evaluated, 22 were assessed on the basis of the relevant themes from the data concerning the enablers and challenges, as indicated in Table 2, whereas the remaining 17 did not yield themes of interest.

Enablers arose from the relative advantage, adaptability, evidence strength, and quality, relative priority, tension for change, knowledge and beliefs about the intervention, self-efficacy, culture, and engaging constructs. These include the urgent need for healthcare digitalization, reshaping the daily work of healthcare professionals, preparing students for their future medical work by increasing their knowledge and attitudes, decreasing their doubts about eHealth technologies, and thus enhancing the quality of patients' care as shown in Fig. 2.

On the other hand, challenges arose from complexity, design quality and packaging, external policies and incentives, cosmopolitanism, peer pressure, readiness for implementation, compatibility, available resources, engagement, implementation climate, knowledge and beliefs about the intervention, self-efficacy, executing, reflecting and evaluating, and engaging constructs. These include concerns of erosion of basic clinical assessment, fear of abandonment of a generalist approach to healthcare, loss of patient contact due to digitized medicine, lack of infrastructure and educational materials to

Table 2 CFIR constructs and their related enablers or challenges to digital health integration in medical education curricula

CFIR domain	CFIR construct	Enabler or challenge	Explanation for enablers and challenges
Intervention characteristics	Relative advantage	Enabler	Improving students' ability to provide quality patient care
	Relative advantage	Enabler	Preparing students for their future medical work
	Adaptability	Enabler	Decrease students' doubts about digital Health technologies
	Evidence strength and quality	Enabler	Improve work efficiency among learners
	Evidence strength and quality	Enabler	Improve access to care in underserved communities and the quality of care in remote and rural communities and reduce medical errors
	Complexity	Challenge	Erosion of basic clinical assessment skills
	Design quality and packaging	Challenge	Depersonalization by technology
	External policies and incentives	Challenge	Lack of standardization
Outer setting	Cosmopolitanism Peer pressure	Challenge	Lack of collaboration among medical schools due to different mission and friendly competition to produce competent medical graduates
	External policies and incentives	Challenge	Lack of clear policy guidelines for clinical practice
	Peer pressure	Challenge	The exponential growth of technological developments and rapid pace of technology advances
	Relative priority	Enabler	Improving students' ability to provide quality patient care and to satisfy their desire to learn more about digital health concepts
Inner setting	Tension for change	Enabler	Rationalize their intention to use digital tools as physicians
	Culture	Enabler	Reshaping the future daily work of health care professionals
	Readiness for implementation	Challenge	Lack of educational materials to operate digital health classes
	Compatibility	Challenge	Dense nature of the existing undergraduate medical curriculum increase in workload for both students and instructors
	Available resources	Challenge	Lack of Infrastructure (necessary software and hardware, internet) to use respective digital tools or platforms in digital medicine
	Engagement	Challenge	Bureaucratic tendencies
	Implementation climate	Challenge	Lack of protective mechanisms in medical schools for experiential learning and experimentation in terms of safe and innovative spaces
	Knowledge and beliefs about the intervention	Enabler	Improved perception that digital health is an important aspect of patient care

Table 2 (continued)

CFIR domain	CFIR construct	Enabler or challenge	Explanation for enablers and challenges
Individual characteristics	Knowledge and beliefs about the intervention	Enabler	Increase in knowledge in digital health competence
	Self-efficacy	Enabler	Increased overall satisfaction, understanding and willingness to use digital health for chronically ill and elderly patients
	Knowledge and beliefs about the intervention	Enabler	Positive attitudes among medical students and lecturers toward digitization and incorporating digital health into the medical curriculum
		Challenge	Lack of clinically trained faculty with technical expertise to teach digital health and digital health content creation
		Challenge	Negative attitude toward digital health (Difficulties in convincing doctors to use digital services and apps)
		Challenge	Lack of awareness of the need for digital health (perceived usefulness of the courses)
	Self-efficacy	Challenge	Lack of preparedness among students to address digital challenges in their future profession and to take advantage of the technological developments within the medical field
		Challenge	Digital health requires more mental effort
	Engaging	Enabler	Urgent need for health care digitalization
	Executing	Challenge	High costs related to the integration of digital health in medical curricular
Implementation process	Reflecting and evaluating	Challenge	Digitalization seen as a threat to the patient–physician relationship
	Engaging	Challenge	Digital health is not sufficiently integrated in the current undergraduate curricular
		Challenge	Lack of formal teaching

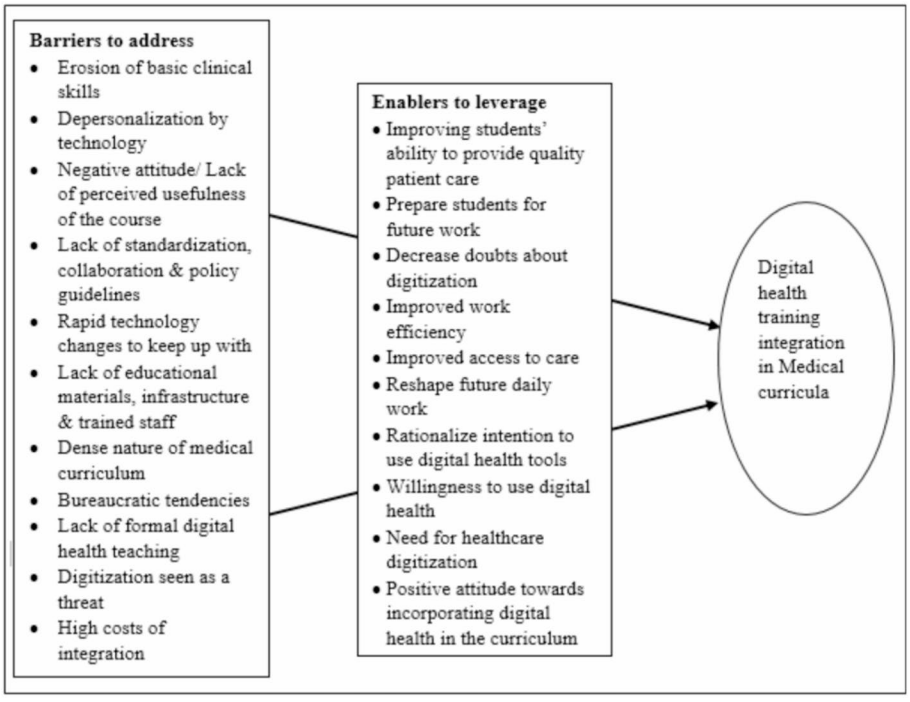


Fig. 2 Challenges to address and enablers

operate digital health classes, the dense nature of the existing undergraduate medical curriculum, bureaucratic tendencies, lack of collaboration among medical schools, lack of standardization and clear policy guidelines, lack of clinically trained faculty with technical expertise to teach digital health, and seeing digitalization as a threat.

3.1 Characteristics of the intervention

Six studies conducted in Germany, China, Europe, and Finland to introduce digital health as a curriculum module and identify undergraduate medical competencies in digital health and their suitable teaching methods highlighted the need to prepare medical students as early as possible in preparation for highly digitized future healthcare systems [5, 12, 18, 32–35]. This is aimed at enhancing the adoption of future digital health processes and technologies, training them in utilizing digital health applications [36], and preparing them for their perceived job qualifications to maintain their clinical responsibilities.

The integration of the digital health module in the medical curricula was reported to potentially decrease students' doubts, reduce fears, change their attitudes and promote enthusiasm for digital health technologies [5, 17, 18, 37, 38]. Additionally, it was reported to promote a culture of innovation, improve work efficiency among learners [39, 40], and facilitate access to quality care in remote and rural communities and reduce medical errors [35, 36].

However, several studies have noted concerns about the erosion of basic clinical assessment skills like physical examination of patients which is critical to clinical care due to overreliance on digital skills for imaging, scanning, and laboratory results [40]. A similar study reported concerns regarding depersonalization by digital technologies, where doctors may spend a considerable amount of time on their computers and do not maintain physical eye contact with patients, which affects doctor-to-patient interaction and results in the fear of abandonment of a generalist approach to healthcare and the loss of patient contact due to digitized medicine [40, 41]. These have been noted to result in incorrect decisions, which raises ethical concerns [17, 35].

3.2 Inner setting

The urgent need to integrate digital health into the medical curriculum due to the growing use of digital technologies within health care has been reported. This is aimed at improving students' ability to provide quality patient care, and to learn more about digital health concepts such as data protection, management, analysis, and AI in their medical courses to rationalize their intention to use digital tools as physicians [5, 32, 34–36, 39, 41–49].

However, this integration would require more evidence of the effectiveness of these digital technologies, a strong and integrated IT infrastructure in healthcare institutions [49], and centralized IT training to improve the current system of training [50]. Concerns regarding the lack of infrastructure in terms of the software and hardware necessary to use digital tools or platforms in digital medicine, IT insecurity [50], a lack of backup systems in the event of system failure [41] and a lack of access to the internet [35] have been raised as key challenges to the digitalization of medicine. This, in the long run, may hinder students' ability to cope with the technical requirements of the program.

Nine studies have been conducted in Germany, China, Finland, Europe, Nigeria, and Australia [5, 12, 17, 18, 32, 33, 41, 43, 46, 47] underscoring how digital health reshapes the future daily work of health care professionals by changing the way doctors and patients deal with each other and simplifying doctor consultations and ensuring 24/7 doctor access and medical on-the-spot support from paramedics [16]. Additionally, digital tools are described as key in facilitating the diagnosis, treatment, and rehabilitation of various diseases [42] and supplementing traditional treatment and consultation [16, 37].

Several studies have reported the dense nature of the existing undergraduate medical curriculum [5, 49, 51] in comparison with the broad content of digital health [51], which makes the integration of the new training module challenging. This means an increase in workload for both students and instructors [16, 36].

Additionally, the lack of educational materials to operate digital health classes in China [51], lack of digital health-related formats in medical education in Germany [5], and lack of protective mechanisms in medical schools for experiential learning and experimentation in terms of safe and innovative spaces in Singapore and Canada [44, 52, 53], have been reported as factors hindering students from practicing with digital health innovatively, which makes integration into medical curricula difficult.

Administratively, bureaucratic inertia due to faculty members' lack of awareness regarding the evolution of clinical practice [54], which makes it difficult to adjust the medical curriculum to incorporate new changes and requires considerable energy and resources to convince policymakers and medical school faculty, has been reported in Singapore. These efforts are counteracted by great resistance from individuals who are not well versed with modern technology [52].

3.3 Outer setting

A lack of collaboration among medical schools due to different missions and friendly competition to produce competent medical graduates and a lack of standardization and clear policy guidelines regarding digital use in clinical practice were reported in Singapore as challenges hindering the integration of digital health in medical curricula [49]. Additionally, the exponential growth of technological developments and rapid pace of technology advances leave educators with the responsibility of keeping up to date regarding current trends in digital health innovations [40], making it challenging to train medical students in certain digital health technologies, yet they may not be applicable in the next few years.

3.4 Characteristics of individuals

A pre-post test study carried out in Germany among students who participated in the transdisciplinary digital health curriculum at the University of Rostock reported an increase in knowledge of digital health competence and better overall coverage of digital health learning objectives among clinical students [39]. Additionally, an evaluation study of clinical telemedicine/e-health module integration in the curriculum among medical students at the University of Zurich reported increased clarity about the need for telemedicine, increased overall satisfaction and understanding of telemedicine, and increased willingness to use telemedicine for chronically ill and elderly patients [37]. Another quantitative study [38] at the University of Southern California that integrated case conference series reported an increase in students' knowledge of digital

competencies, familiarity, and comfort with smart pills; digital therapeutics; health and wellness apps for smart devices; and telehealth and improved their perception that digital health is an important aspect of patient care.

Positive attitudes among medical students and lecturers toward digitization and incorporating digital health into the medical curriculum have been documented as key enablers for digital health training integration. Two studies conducted in Germany and the Netherlands [5, 19] reported that medical students had a positive attitude toward this integration and were willing to play a central and active role as mediators of digital health literacy to patients. Additionally, positive attitudes toward the digitization of healthcare, the use of digital tools in different domains within the medical field, and the intention to use digital tools as physicians have also been reported in Germany and Romania [17, 42]. This could be due to the perceived belief among students about digital health [36] and that the future is digital [43] in anticipation that medicine will be fundamentally changed by new digital enablers in the next few years [47].

However, the lack of preparedness among students to address digital challenges in their future profession and to take advantage of technological developments within the medical field [19, 37, 41, 47, 51, 53] and the lack of skills to use these digital tools [5, 38, 47, 49, 50, 55], difficulties in convincing doctors to use digital services and apps [16, 18, 47], are described as key challenges that may counteract the future implementation of digital technologies. This could be attributed to the lack of clinically trained faculty with technical expertise to teach digital health and digital health content creation [34, 50]. This makes it difficult for students to understand different terminologies such as data protection and artificial intelligence used in digital health [16, 37, 50, 51], which subsequently results in poor digital health skills [5, 38, 41, 43, 46, 49, 53, 55]; negative attitudes toward digital health [41, 46]; and a lack of awareness of the need for digital health [51]. Therefore, early and increased integration of digital medicine topics can potentially bridge this gap.

A study in Saudi Arabia noted that digital health requires more mental effort [36], and even recent advances in digital health, such as the use of artificial intelligence, viewed more as encumbrances than as useful assistance [16].

3.5 Implementation process

Ten studies reported the urgent need for healthcare digitalization [17–19, 32, 33, 38, 39, 46, 49, 56] as a continuous process to improve the analysis of patient data to make evidence/based data-driven clinical care [18]. This digitization should be accepted by those who perceive it as relevant to their work [39]. This is meant to act as an accessory tool to improve their performance, save time, make their work easier [16], and improve patient safety within the operations theatre [56], not as a threat to their jobs [17]. However, digitalization was reported as a threat concerning the patient–physician relationship due to lack of physical presence [57]. A study by Gillissen and colleagues reported that unreliable and noncertified internet sources that patients always receive may confuse the patient–doctor relationship, especially when the physician disagrees with the patient's medical inquiry [16].

Six studies reported that digital health is not sufficiently integrated into the current undergraduate curriculum in Germany, Australia, Saudi Arabia, Singapore, or the United Kingdom [12, 34, 39, 50, 51, 53]. This is due to a lack of formal teaching where digital

health is integrated into other topics, while another study in Singapore reported inconsistent opening of digital health classes, and another study in Saudi Arabia reported high costs related to the integration of digital health in medical curricula [34].

4 Discussion

4.1 Summary of evidence

Guided by the CFIR framework, our review sought to summarize published evidence regarding enablers for and barriers to the integration of digital health education in medical curricula from the literature to inform policymakers on factors that should be considered for future integration. Enablers identified include the urgent need for healthcare digitalization, reshaping the future daily work of healthcare professionals, preparing students for their future medical work by increasing their knowledge and attitudes, and decreasing their doubts about digital health, thus enhancing their quality of patient care. In contrast, concerns of erosion of basic clinical assessment, fear of abandonment of a generalist approach to healthcare, loss of patient contact due to digitized medicine, lack of infrastructure and educational materials to operate digital health classes, the dense nature of the existing undergraduate medical curriculum, bureaucratic tendencies, lack of collaboration among medical schools, lack of standardization and clear policy guidelines, lack of clinically trained faculty with technical expertise to teach digital health, and seeing digitalization as a threat were identified as barriers to digital health integration in medical training.

In his remarks during the unveiling of the WHO's Smart AI Resource Assistant for Health (SARAH), a generative AI for understanding the risk factors for the leading causes of death in the world, Dr. Tedros Adhanom Ghebreyesus, the director-general of the WHO, noted that "the future of health is digital" [58]. This cannot be disputed given that information communication technologies (ICTs) have been underscored by the 2030 global agenda for sustainable development as key in accelerating human progress and bridging the digital divide gap [59]. The advent of digital technologies such as wearable devices, computerized clinical decision support systems, and telemedicine, which are frequently used in healthcare settings, is a testament in which digital health is a larger component of the overall healthcare system and plays an important role in improving the technical performance and quality of delivered care [9]. The use of these digital tools in clinical practice seems inevitable given their widespread preference among users. This, therefore, calls for mechanisms that can carefully consider addressing the identified challenges and leveraging the identified enablers to help introduce digital health to these future users as part of their formal and informal education. This is aimed at the development of a critical digital health mindset with openness to innovation, and the ability to assess the ever-changing health technologies needed to translate research into clinical care should be prioritized [18].

The desire to digitize health to allow seamless collection and use of data to facilitate evidence-based medicine for enhancing patient-centered care requires building the capacity of future users to facilitate adoption and usability. Therefore, training users as early as possible fosters intervention ownership and acts as a mindset and attitude reset for those learners with negative attitudes/low perceptions of the usefulness of digital health [60]. In his commentary, Dr. Rashad Bhyat noted that the next generation of physicians "will be the most digitally savvy to date" and advocated for tools and resources

that can facilitate optimal utilization among these physicians to benefit their patients and facilitate better clinical experience [61]. Training clinicians in the practical use of these technologies as early as possible has long been overdue [11].

The already dense nature of the medical curriculum makes it challenging for planners to add more content such as digital health [40], which may be attributed to faculty resistance to change toward an integrated curriculum [62, 63]. Truthfully, the pace at which the world is advancing toward digitization is proof that traditional medical practice will not remain the same. The National Academy of Medicine outlined key areas where digital health is currently being applied in almost every aspect of medicine, including health information (digital records and dashboard), knowledge generation (epigenetics, epidemiologic modeling), knowledge integrators (predictive analytics and decision aids), personal health devices, telemedicine, diagnostics, imaging for pinpoint assessment and interpretation, dose use and monitoring, implantable devices, and robotics for surgical practice, among others [64]. Therefore, burying our heads in the sand even with these evident projections and the high penetration rates of digital technologies and how they are at the forefront of revolutionizing healthcare would be a great inconsideration of our time. In his book "Future Shock", Alvin Toffler declared that "The illiterate of the twenty-first century will not be those who cannot read and write, but those who cannot learn, unlearn, and relearn" [65]. It is, therefore, time we learned, unlearnt and relearnt through rethinking and reimagining the delivery of clinical practice in the 21 st century.

The existing knowledge gap regarding the importance of these digital health interventions and the lack of perceived usefulness of digital health courses [51] affects the overall success of the implementation of these well-intended interventions. This is exacerbated by the negative attitudes toward digital health [41, 46] and the view of digitization as a threat to patient–physician relationships [56], which have been noted as a significant challenge to digital health integration in medical curricula. Institutional training mechanisms such as sensitization programs in the form of webinars underscoring the role of digital health and debunking myths about digital health may play an important role in addressing these challenges and setting a stage for smooth integration and utility.

Whereas some of the identified challenges are indeed external, organizational, and procedural, such as a lack of policy guidelines, standardization, and a lack of trained staff, which may be beyond the control of individuals, devising means for lessening their negative impact on digital health integration is crucial. This requires concerted efforts and political commitment from governments and international organizations to guide the importance of this integration toward the global digital health agenda 2030 and the necessary moral and financial support toward establishing standards, policy frameworks, and guidelines for this integration in medical curricula. Alternatively, longitudinal studies assessing the outcomes of the intervention by comparing students enrolled in a medical curriculum that utilized digital health in their medical practices may offer more reasons for institutions to weigh the benefits and risks of churning digitally competent medical workers.

Using the ERIC [24], we identified 16 implementation strategies, as indicated in Table 3, that can be used to mitigate the identified challenges. These include providing consolidated funds tailored to support integration and technical assistance during the learning process; setting up a dedicated digital health infrastructure to support the experiential learning process, starting with both elective-based and audited modular

Table 3 Matching the challenges with implementation strategies per the ERIC framework to guide smooth integration

Challenges	ERIC implementation strategies	Application of the strategies
High costs of integration	Access new funding	Provision of consolidated funds tailored to supporting the integration
Digital health requires more mental effort	Centralize technical assistance	Provide technical assistance to learners during the process of learning
Lack of Infrastructure (necessary software and hardware, internet) to use respective digital tools or platforms in digital medicine	Change physical structure and equipment	Intentionally set up the digital health infrastructure (dedicated digital health labs, provide dedicated internet and digital resources) to support experiential learning process
Lack of protective mechanisms in medical schools for experiential learning and experimentation in terms of safe and innovative spaces		
Dense nature of the existing undergraduate medical curriculum increase in workload for both students and instructors	Conduct cyclical small tests of change	Adopt an elective based modular approach, or an audited digital health module, evaluate the performance outcomes and areas of refinement
Digitization seen as a threat	Conduct educational meetings and outreach visits	Aimed at raising awareness and educating key stakeholders about the role and potential of digital health and its integration in medical curricular
The exponential growth of technological developments and rapid pace of technology advances		
Depersonalization by technology		
Erosion of basic clinical assessment skills		
Bureaucratic tendencies	Conduct local consensus discussions	Involve key stakeholders (university leaders, top management, professional bodies) as early as possible during planning and curriculum design
Lack of formal digital health teaching	Develop a formal implementation blueprint	Establish a clear roadmap toward formalization of digital health module teaching
Lack of collaboration among medical schools due to different mission and friendly competition to produce competent medical graduates	Develop academic partnerships	Partnering with sister institutions for benchmarking, knowledge, and training resources sharing
Lack of standardization	Develop and organize quality monitoring systems	Standardize the process of teaching at institutions by establishing clear monitoring processes for better outcomes
Lack of educational materials to operate digital health classes	Distribute educational materials	Development and distribution of key digital health educational materials including guidelines, reading materials
Negative attitude	Identify and prepare champions	Identify passionate, vocal individuals in institutions to advocate for integration and overcome resistance to change
Lack of perceived usefulness of the course	Identify early adopters	Early adopters within institutions for other learners to learn from their experiences
Lack of clear policy guidelines for clinical practice	Involve executive boards	Benchmark on the expertise of governing structures at institutions to offer guidance and foster policies regarding digital health integration within their institutions
	Use advisory boards and workgroups	Additionally, these stakeholders may play a role in providing input and advice on the digital health module integration in medical curricular roadmap
Lack of preparedness among students to address digital challenges in their future profession and to take advantage of the technological developments within the medical field	Prepare consumers to be active participants	Equip learners to actively ask questions and seek for guidance during learning process about the importance of digital health in their future profession.

Table 3 (continued)

Challenges	ERIC implementation strategies	Application of the strategies
Lack of trained staff	Recruit, designate, and train for leadership	Intentionally allocate adequate funding to facilitate the recruitment of key staff with specific training in digital health

approaches; raising awareness and educating key stakeholders about the potential of digital health and its integration in medical curricula; involving key stakeholders as early as possible during planning and curriculum design; establishing a clear roadmap toward the formalization of digital health module teaching in institutions; partnering with other institutions for benchmarking, knowledge, and training resource sharing; establishing clear monitoring processes for better outcomes; distributing key digital health educational materials; identifying passionate, vocal individuals, early adopters in institutions to advocate for integration and overcoming resistance to change; benchmarking on the expertise of governing structures at institutions for guidance; and recruiting new staff with specific training in digital health are key implementation strategies that can mitigate the identified challenges.

Although this review has shown that there has been global progress toward the incorporation of digital health training in medical curricula, their integration in Africa is still minimal as an evidenced by a few number of papers included in this review. This implies a geographical imbalance in the literature. Although most of these factors are seemingly understandable, and clear-cut throughout all the nations, the transferability of these findings across diverse educational contexts may reveal unique findings and enablers for integration of digital health in the education curriculum.

The evidence shows that significant strides toward digital adoption are being made, as more than 47 countries have already developed digital health strategies for building and strengthening resilient health systems [66]. Although this approach is commendable, progress toward the WHO's advocacy for ensuring digital literacy integration in formal and informal education curricula by African countries remains rare compared with that of European nations and North America. This indicates slow progress toward having all healthcare workers prepare to deploy and use digital health tools in their daily work. Future implementers need to envisage mechanisms for integrating digital health into medical curricula.

4.2 Implications for policy and implementers

Training users as early as possible fosters intervention ownership and acts as a mindset and attitude reset for those learners with negative attitudes/low perceptions of the usefulness of digital health. This requires a systematic approach to identifying bottlenecks and capitalizing on the available enablers to ensure smooth integration at early entry points, such as medical curricula. The question left to all of us is whether to let these bottlenecks remain and maintain the way things are even when it is evident that digital health is here to stay or prepare and brace ourselves and our institutions by garnering the necessary support toward this digital future.

4.3 Strengths and limitations

To the best of our knowledge, our review is the first to synthesize evidence for policymakers, future researchers, and implementers about contextual multilevel bottlenecks that should be addressed to realize opportunities for digital health integration in medical curricula. If these enablers are leveraged, they can improve digital health integration outcomes in medical curricula. Failure to address them might compromise the quality of digital integration. Furthermore, our review was based on the key implementation science principles of identifying evidence-practice gaps and performing data analysis and extraction on the basis of a theoretical implementation framework.

However, our study was not without limitations. First, our review contributes to the understanding of digital health training integration by reporting several studies that have integrated digital health training as a part of the curriculum and other studies that only report perceived experiences, attitudes, and perceptions. We believe that several other institutions have integrated digital health training but have not published their experiences in peer-reviewed journals [20, 21]. However, a search of their institutional databases can yield better outcomes. Therefore, it is important to note that there could be institutions that have integrated digital health into their medical curriculum but have not published their experiences but were not included in the final review. Additionally, we did not include papers that focused only on assessing digital competencies if they did not report enablers and challenges or studies that reported factors related to the use of e-learning or digital education tools. Lastly, the use of ERIC framework to suggest potential strategies for addressing the challenges to integrating digital health in medical curriculum, needs to be cautiously interpreted, given that these strategies are rather suggestions that have not been empirically evaluated but should rather be adopted based on their feasibility and applicability within their settings.

5 Conclusion

The integration of digital health training in medical curricula cannot be successful if bottlenecks are not identified and if mechanisms are put in place to address them. Global progress toward integrating digital health literacy in formal medical training curricula remains slow. Thus, there is a need for concerted efforts and political commitment from governments and international organizations to guide the importance of this integration toward the 2020–2025 global digital health agenda and the need for moral and financial support to establish standards, policy frameworks, and guidelines for this integration in medical training curricula. Therefore, the successful integration of digital health in medical training requires careful efforts to address these existing challenges and leverage these enablers.

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

Author contributions

W.T, A.M, D.B, F.K, R.M, N.T, D.A, S.T and E.C.A were jointly involved in the conception and design of the study aims and questions. W.T, G.N, R.N, I.W, M.R, J.P.B, and A.M were involved in reviewing and screening abstracts and full texts for inclusion and extracting data from the included papers. W.T, S.T, J.N, G.N D.A, F.K, E.C.A, A.M, R.W and J.N.S contributed to

the data analysis. W.T drafted the manuscript. R.N, M.R.G, R.W, K.G, and I.W provided substantial feedback and edits to the drafts. All the authors critically reviewed, read and approved the final version of the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

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Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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