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A landscape analysis of digital health technology in medical schools: preparing students for the future of health care

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Abstract
Although Digital Health Technology is increasingly implemented in hospitals and clinics, physicians are not sufficiently equipped with the competencies needed to optimize technology utilization. Medical schools seem to be the most appropriate channel to better prepare future physicians for this development.
The purpose of this research study is to investigate the extent to which top-ranked medical schools equip future physicians with the competencies necessary for them to leverage Digital Health Technology in the provision of care. This research work relied on a descriptive landscape analysis, and was composed of two phases: Phase I aimed at investigating the articulation of the direction of the selected universities and medical schools to identify any expressed inclination towards teaching innovation or Digital Health Technology. In phase II, medical schools' websites were analyzed to discover how innovation and Digital Health Technology are integrated in their curricula. Among the 60 medical schools that were analyzed, none mentioned any type of Digital Health Technology in their mission statements (that of the universities, in general, and medical schools, specifically). When investigating the medical schools' curricula to determine how universities nurture their learners in relation to Digital Health Technology, four universities covering different Digital Health Technology areas were identified. The results of the current study shed light on the untapped potential of working towards better equipping medical students with competencies that will enable them to leverage Digital Health Technology in their future practice and in turn enhance the quality of care.

Keywords Digital health technology, Innovation, Competencies, Higher education, Medical education, Medical schools, Quality of care

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Introduction

Over the last decade, Digital Health Technology (DHT) has received growing attention from scientists, practitioners, media, and the general public. This observation can be explained by the increasing number of adopters using technology such as wearables to collect health-related data [1, 2]. The more recent surge can be attributed to the COVID-19 pandemic that has accelerated change, forcing hospitals and health authorities to investigate alternative ways to protect the population and deliver care to patients who are self-isolating or in lockdown [3–5]. Although COVID-19 has put telehealth or telemedicine in the front seat, this technology represents only a small part of DHT. The World Health Organization (WHO) defines DHT as 'the use of information and communications technology in support of health and health-related fields' [6]. Another more recent WHO report defines digital health as 'the field of knowledge and practice associated with the development and use of digital technologies to improve health' [7].

DHT encompasses a wide range of emerging technologies from activity trackers and smartwatches that have demonstrated their capacity to detect serious health conditions. For example, stroke is the second leading cause of morbidity and mortality worldwide, and its risk factors include smoking, obesity, dyslipidemia, diabetes, hypertension, heart disease, and atrial fibrillation. DHT {e.g., MyRisk_Stroke Calculator [8]} can be used to calculate the stroke risk from all those individual risk factors for a patient. This would allow the patient and the physician to improve holistic primary stroke prevention [9] and potentially allow the patient to choose which risk factors to moderate. Atrial fibrillation is a cardiac arrythmia which quintuples the risk of stroke. The symptoms may be clinically silent to the patient. Wearable devices such as the Apple watch can detect atrial fibrillation and alert the patient or caregiver, potentially saving a life by allowing a timely intervention [10]. Similarly, Mitsi et al. (2022) describes the use of wearables to detect seizures [11]. Previously, patients used to rely on paper diaries to record their seizures which clinicians would then use to decide on required drug doses. However, wearable technology may detect seizures that are not necessarily apparent to the patient, giving the physician and patient a more accurate log of seizures. Virtual Reality (VR) can support and facilitate the training of (future) surgeons by allowing them to practice surgery in a simulated setting before they perform procedures on patients, which improves patient safety [12]. VR can also be used in the management of pain (chronic or perioperative) which could potentially reduce the requirement for stronger pain medications, reducing the risk of medical side effects [13–15]. Artificial Intelligence (AI) can support radiology and reduce human error by learning to detect abnormal masses (complex shapes) in X-Ray images which may help to detect abnormalities or cancers faster than the human eye [16, 17]. DHT, such a smart phone application, can enable pregnant women to self-monitor their blood glucose level hence managing their condition from home and in a timely manner. This in turn can lead to improved outcomes for the pregnancy [18]. Multiple studies have shown that mobile health applications can reduce the HbA1c (i.e., average blood glucose over the last three months) in patients with all types of diabetes by supplying them with improved information in a timely manner, allowing the patient to control their diabetes before the traditional clinic appointment takes place [19]. Additionally, wireless continuous blood glucose monitors and insulin pumps can allow much more precise control of blood sugar levels which gives the patient more autonomy and lifestyle freedom, by presenting real-time data that enables timely intervention [20]. Sometimes patients support and encourage each other through exchanging technical insights, perhaps virtually. Accordingly, it is important for medical students to understand the positive impact that this type of DHT can have on patients' self-efficacy, and for DHT to be taught in medical schools.

Although DHT, including Electronic Health Records, is increasingly implemented in hospitals and clinics [15], and there are several relevant competency frameworks {e.g., UK National Health Service Digital Healthcare Technologies Capability Framework [21] and Australian Digital Health Capability Framework [22]} that suggest embedding DHT into medical curricula and training, evidence shows that physicians are not equipped with the competencies necessary to optimize technology utilization. A recent survey revealed that only 6% of physicians and physicians-in-training are familiar with AI [16]. In another recent study, the authors found a very low level of familiarity of doctors and medical students with AI [17]. The study also highlights no significant differences in AI knowledge between doctors and medical students. In addition, it is known that clinicians tend to be concerned about the accuracy of the data collected from wearables [18]. These unused data, algorithms, and devices represent a significant missed opportunity around improving the quality of care, including but not limited to its accessibility. This can be a consequence to the work cultures which are hostile to innovation, resistance from physicians, lack of trained medical staff, lagging DHT knowledge, and reluctance to change [19, 20, 23]. It is possible that outdated Information Technology (IT) systems or even lack of planning for technology advancements may discourage the use of DHT [24].

Medical schools seem to be the most appropriate starting point to equip future physicians with the skills, knowledge, and attitudes to leverage DHT in their clinical practice. When surveyed, 80% (360 subjects) of the students expect DHT to be part of medical curricula [25], and in another research study, medical students are expecting to receive as part of their curricula some education on topics related to technology [26]. However, in reality, more than 50% of the medical students perceive their DHT competencies as poor or very poor [25]. Existing research stresses the fact that medical school offerings are rather limited. In a recent scoping review that investigated DHT initiatives in medical schools, the authors found that most of the studies focused on medical informatics and Electronic Medical Records (EMR). Only 9% and 3% of the studies discussed telehealth and mobile health, respectively [27]. A recent paper, referring to the use of DHT, highlights the gap that exists between the competencies that are required to address patients' needs and the training that future physicians receive [23]. DHT has great potential, yet there is a lack of literature on medical schools' role in preparing future physicians to use DHT. The purpose of this research study is to investigate the extent to which top-ranked medical schools equip future physicians with the competencies necessary for them to leverage DHT in the provision of care. Therefore, this study's research questions are:

- How many top-ranked medical schools mention DHT or innovation in their respective mission statement and/ or description of curriculum?
- How are top-ranked medical schools preparing medical students for the future of health care, in general, and DHT, specifically?

Table 1 Research design phases

Phase	I	II
Input	• Mission statement of university • Mission statement of medical program • Content of medical program official websites (including but not limited to curriculum of medical program- if available)	Content of the official websites of the medical program (including but not limited to curriculum of medical program- if available)
Process: data analysis	Systematic scanning to identify any mentioning of DHT, or the word (or derivatives of the word): 'innovation'	Investigation to develop an understanding of the extent to which the included medical programs are striving to nurture relevant competencies
Output	A value of '1' or '0' was used to signify presence or absence, respectively, of the target mentioning	Description of extent of intervening and nature of intervention of medical programs, where applicable

Methods

Research design

The current study relied on a descriptive landscape analysis which is a scanning tool used mainly in the field of public health to develop an understanding of the status quo of a particular community [28]. This tool is usually deployed in the field of public health prior to introducing any community-based program to confirm that there is a need for the proposed program. This characteristic of descriptive landscape analysis makes it particularly fit for the current study which is meant to generate evidence to reinforce decisions concerning the learning and teaching of DHT in medical schools. The landscape analysis reported upon in the current study is based on the systematic analysis of purposefully selected websites, and hence adheres to the Checklist for Assessment and Reporting of Document Analysis (CARDA) [29]. This checklist was designed to substantiate document analyses in health professions' education research.

The current study was composed of two phases as shown in Table 1. The medical schools included in the research were selected based on the Times Higher Education (THE) World University Rankings 2021 [30]. Since it is established that environmental variables, such as culture and socio-political aspects, affect universities, and their learning and teaching [31, 32], a stratified selection technique was adapted to enable equal representation from all around the world. The 10 top-ranked universities of the THE subcategory of 'clinical and health' from each continent: Asia, Africa, North America, South America, Europe, and Australia, were selected. Phase I aimed at investigating the articulation of the direction of the universities and medical schools (as displayed on their websites) to identify any expressed inclination towards teaching innovation or DHT. In phase II, medical schools' websites were analyzed to discover how innovation and Digital Health Technology are integrated in their curricula. This systematic analysis was initially conducted to inform decisions around learning and teaching of DHT in a university of medicine and health sciences in the middle east. The authors decided to proceed with publishing the findings to share them with the community-at-large given the perceived value of the insights that the analysis generated. This research was approved by Mohammed Bin Rashid University of Medicine and Health Sciences (MBRU)- Institutional Review Board (IRB) (MBRU IRB-2024-96).

Data collection

Data was gathered, from April to June 2022, in a custom-made data entry framework. Two clusters of data points were retrieved for each of the included medical schools. First, with the intention of developing a systemic understanding of the direction of the learning and teaching of the respective medical schools, and their interest and commitment to teaching DHT, the mission statements of the medical schools and of the encapsulating universities were retrieved and inserted into the preset data collection sheet. Second, the curricula of the included medical schools were downloaded. The data points of the second cluster were related to the six key emerging areas of DHT: digital health, mobile health, AI, extended realities (i.e., augmented reality and VR), wearables, and the future of health delivery. Below is an outline of the pinpointed data points:

- Whether, or not, the area is taught? (Y/N)
- Is the area taught as a non-elective? (Y/N)
- What is the duration of the corresponding learning opportunity/ educational offering?
- Is this learning opportunity/ educational offering part of the medical curriculum, considered co-/ extra-curricular, or part of an alternative curriculum?
- What is the delivery mode?

Data analysis

The analysis was done collaboratively, in a series of discussion sessions, by three researchers (TB, FO, CK). To start with, the mission statements (of the medical schools and the encapsulating universities) and the medical programs' curricula were systematically scanned to identify any mentioning of DHT, or the word (or derivatives of the word): 'innovation'. The rationale for using 'innovation' (or derivatives of 'innovation') as a search term, along with DHT, is to ensure that we capture all relevant content in the search. Since digital health is one of the biggest innovations in health care in recent years [33], if a university claims to be innovative, it would be anticipated that they are teaching digital health in their medical curriculum. Upon identification of those keywords, the researchers strived to interpret the context of the respective sentences to ensure that the identified keywords are used to describe the competencies that the school/ university aims to develop in its students, rather than describing their facilities, and/ or their learning and teaching (i.e., medical education). When such mentioning was identified, the researchers worked towards reaching a consensus. A value of '1' or '0' was put into each corresponding cell of the tailor-made data entry framework to signify presence or absence, respectively, of the target mentioning. Similarly, when a medical school covered any of the DHT areas, the value of '1' was assigned. This approach generated quantitative, count data. Next, an investigation of all the included medical programs' official websites was carried-out to develop an understanding of the extent to which the respective programs are intervening to nurture relevant competencies (when applicable). This was primarily led by the preset variables, defined in the custom-made framework of data collection.

Results

Out of the 60 included universities, three did not have a distinct medical school and hence, were excluded.

Phase I

None of the 57 remaining universities mentioned DHT in their university mission statement. However, as illustrated in Fig. 1, nine universities referred to 'innovation' (or derivatives of 'innovation') in their universities' mission (9/57, 15.8%) and the same number mentioned innovation in their medical school's mission statements (9/57, 15.8%). Amongst these, only one university: Fudan University, mentioned 'innovation' (or derivatives of 'innovation') in both mission statements (1/57, 1,8%). There were four universities that turned out to offer at least one DHT (4/57, 7.1%), with one of those universities including digital health as part of its medical school's mission statement (Yale University). Only one of those

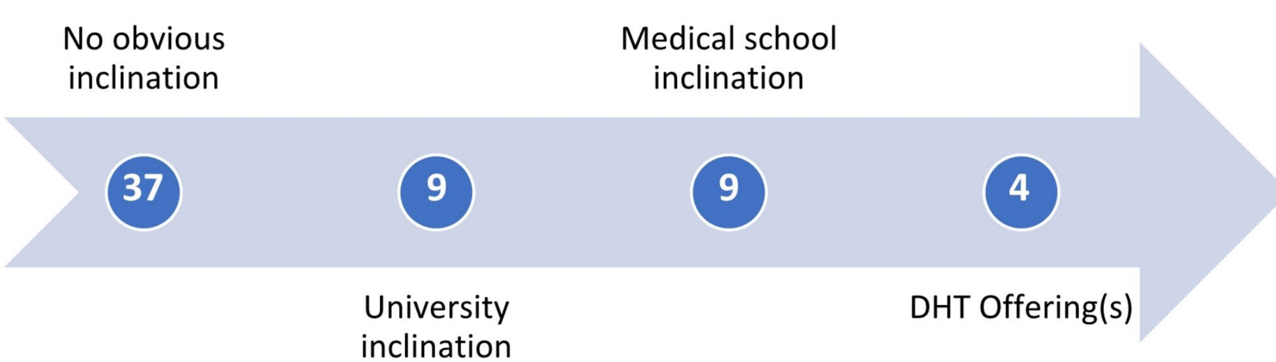

Fig. 1 An outline of a suggested evolution of medical schools in relation to teaching DHT. Most medical schools (no.=37) appeared to have no obvious inclination to teach DHT, nine medical schools appeared to have the inclination to teach DHT as indicated in their university's mission, nine medical schools appeared to have the inclination to teach DHT as indicated in their medical school's mission, and four medical schools have at least one obvious DHT offering

Table 2 List of universities the refer to the word: 'innovation' (or derivatives of 'innovation'), as part of their university and/ or medical school mission statements, including those which teach DHT, as described in their curricula

Universities which mention 'innovation' (or derivatives of 'innovation') as part of their mission statement	Universities which mention 'innovation' (or derivatives of 'innovation') as part of the medical school's mission statements	Universities offering DHT classes
Undergraduate	*Undergraduate*	*Undergraduate*
1. Fudan University	1. King's College London	1. University of Zurich
2. University College London	2. Charité - Universitätsmedizin Berlin	*Postgraduate*
3. National University of Singapore	3. University of Sao Paulo	2. John Hopkins University
4. University of Hong Kong	4. Cairo University	3. Stanford University
5. National Taiwan University	5. Ain Shams University	4. Yale University
6. Mansoura University	6. University of KwaZulu-Natal	
7. Pontifical Javeriana University	7. Fudan University	
Postgraduate	*Postgraduate*	
8. Macquarie University	8. Griffith University	
9. McMaster University	9. University of Pennsylvania	

Table 3 Summary of DHT courses

University	DHT courses offered
John Hopkins University	Design lab
Stanford University	Biodesign for digital health; Biodesign innovation; Technology assessment and medical device regulations
University of Zurich	E-health; Telemedicine; AI
Yale University	New ventures in healthcare and life sciences

four universities offer an undergraduate medical program (University of Zurich), all the rest offer postgraduate medical programs (John Hopkins University, Stanford University, and Yale University).

Among the nine universities that mentioned 'innovation' (or derivatives of 'innovation') as part of their university mission statements, seven were undergraduate and two were postgraduate medical programs. The same proportion appeared among the nine universities which mentioned 'innovation' (or derivatives of 'innovation') as part of the medical school's mission.

Figure 1; Table 2 summarize the findings, answering the current study's first research question 'How many top-ranked medical schools mention DHT or innovation in their respective mission statements and/ or description of curriculum?'.

Phase II

Upon reviewing how universities nurture DHT through their curriculum, it was found that four universities cover different DHT areas (Table 3). However, none of those four universities indicated, as part of their mission statements, their attention to nurturing competencies around technology or innovation. The university that was found to offer the most DHT activities was Stanford University. It turned out to offer its medical students, through its innovation arm: Byers Center for Biodesign, three types of programs that nurture DHT competencies. These three programs rely on a problem-based approach whereby subject matter expects teach brief, compact knowledge capsules; these offerings are activated through group projects. The three programs are electives and carry three or four credits. These three programs include:

1. Biodesign for Digital Health: a quarter-long course engaging multidisciplinary teams of learners (i.e., medicine and bioengineer students). The learners begin their learning journey by identifying user needs to eventually prototype digital health solutions that effectively address the identified health challenges.
2. Biodesign Innovation: two-quarter-long course engaging multidisciplinary teams of learners (i.e., medicine, bioengineering, mechanical engineering, and operation and IT). This course aims at teaching students the science of innovating in the field of health. The learners acquire knowledge about processes, and apply these processes to identify and characterize unmet health needs in order to invent and evaluate new solutions to address these needs. There is also a briefer version of the respective program which is offered to medical students only.
3. Technology Assessment and Medical Device Regulations: a quarter-long course engaging primarily medical students as well as engineers. This course introduces students to modalities and techniques used by regulators and consumers to study the safety, effectiveness, and economic value proposition of select health technologies.

Johns Hopkins University, similar to Stanford University, offers DHT classes as extra-curricular activities. More specifically, it offers a course entitled: Design Lab, that teaches students human-centered approaches, enabling the students to develop DHT (or prototypes of them) that address existing needs. This offering is within the context of Johns Hopkins University dual degree: Master of Business Administration/ Doctor of Medicine (MBA/MD). In addition, through the Johns Hopkins Technology Ventures, the university offers under- and post-graduate students non-credit courses and activities that promote engagement with (health) innovation. For instance, Fast-Forward is an initiative that offers students resources such as physical spaces for experimentation, accelerators, seed funding, and mentorship.

Besides Johns Hopkins University and Stanford University, the University of Zurich in Switzerland; the only non-American shortlisted university, turned out to offer to second year medical students, as part of its elective offerings, a course on e-health and telemedicine and another course on AI in medicine. Moreover, students (in the University of Zurich) have access to the Innovation Hub that offers learning and development opportunities within the realm of innovation and entrepreneurship as well as accelerator programs. Finally, Yale University, as part of the School of Management, has developed a program on entrepreneurship open to any Yale students. Among the offerings of this program on entrepreneurship is a course, entitled: New Ventures in Healthcare and Life Sciences. This course inspires primarily medical students (while remaining open to any interested student) to strive to 'disrupt' health care. This offering includes lectures on digital health and medical devices. It also includes case studies and projects about identifying user needs and prototyping all the way to commercialization.

Discussion

Principal results

Given the increasing use of DHT in the practice of medicine, the current study intended to analyze the extent to which medical schools are equipping their students with digital health knowhow, preparing them to leverage such technologies in their practice. The current study relied on data from 60 top-ranked medical schools around the world. First, mission statements were investigated to analyze whether, or not, DHT and innovation are factored into the set directions of the universities and their medical schools. The results showed that only nine universities refer to technology in their mission statements, showing willingness to integrate technology as part of their curricula. The curricula of all the included medical programs were then investigated to identify how digital health technology are taught to their students. In total, only four medical schools appear, from their websites, to teach some elements of digital health. The majority of DHT teaching are delivered as part of innovation group projects rather than dedicated lectures, except for the University of Zurich. Though group projects allow students to apply the knowledge contextually, there is a risk that students only focus on one type of DHT. For instance, one cohort could work on chronic pain as a challenge for its innovation project, where they would explore the realm of digital therapeutics or VR, while another cohort could look at wearable technologies to help the population attain a better lifestyle. As a result, students very often do not have the chance to extensively cover the whole terrain of DHT.

The current study highlights several key findings. First, it reveals minimal alignment, in relation to the inclination to teach students technology and innovation, between the mission statements of the universities and their medical schools, and the content of the medical curricula. It is not uncommon for the top-ranked medical schools to refer to how they are equipping students with what is needed for the future of health care. Moreover, amongst the nine universities referring to technology as part of their mission statements (either that of the university or that of the medical school), none of them appear to deliver DHT as part of their medical curriculum, according to their websites. It is possible that medical schools have a DHT offering but this is not advertised on their website. Given the importance of DHT in health care, this observation in of itself is worth taking into account for medical school websites (re)design.

Second, the study highlights that the number of medical schools that teach DHT is critically low despite the recent surge of attention towards their deployment in practice. Today, wearable technologies such as activity trackers can collect continuous data to objectively understand patients' quality of life [34], unlike traditional methods that rely on subjective self-reporting. Not only is that data relevant to monitor patients' lifestyle, but also to create digital interventions to change patients' behavior thereby improving their quality of life [35, 36]. However, many hospitals and clinics do not currently have access to such valuable data to diagnose and monitor patients. This may be due to lack of awareness about the utilization and true value of DHT. Similar comments can be made regarding other DHT, such as: VR, that constitutes an evidence-based treatment modality for reducing both acute and chronic pain [10, 11], as well as digital therapeutics that can complement or replace traditional pills, thereby decreasing potential side effects and improving comfort [37]. As such, the results of the current study reinforce the argument that the lack of integration of DHT in medical schools' curricula represents a crucial missed opportunity with regards to improving the quality of care and preparing medical students for the future of medical practice. Otherwise, given the rapidly evolving technology, this quote will hold true: 'the physicians of tomorrow are taught by the teachers of today using the curriculum of the past' [38].

Upon reviewing the news section of the official websites of the included universities, two universities that publicly share that they are working on developing their DHT teaching offerings were identified. The Charité - Universitätsmedizin Berlin is piloting a new course that includes 22 units (lectures and group projects) covering diverse DHT content from augmented reality and VR, AI, mHealth, telehealth, and 3D printing. The course also includes clinical scenarios such as digital surgical training, value-based digital radiology, and personalized drug therapies in addition to innovation [39]. The University of Zurich is also working towards expanding its DHT offering by 2024 through incorporating into the respective program: programming and computational thinking, mobile health and smart devices, augmented reality and VR, and computer assisted medicine, as well as digital patient-physician communication. Beyond the information systematically collected and analyzed in the current study, there seems to be American universities that provide some digital health teaching to medical students but mostly through extra-curricular and elective classes [40].

It is worth reflecting on the potential successful factors of the integration of DHT teaching offerings in medical curricula and developing an understanding of what the medical schools that appear to teach DHT have in common. Apart from a positive, progressive mindset and the support from academic leads, the integration of DHT in medical curricula seems to require strong multidisciplinary collaborations. The Stanford Byers Center for Biodesign is a good example, in that regard. With the intention of bridging the gap pertaining to the absence of technology expertise in the medical school, it was decided early-on for a formal collaboration to be formed between the respective medical school and that of engineering. A few years after, as well, the business school joined with its expertise on commercialization. While clinicians can teach and explain the value of DHT, it is believed that engineers, such as: computer scientists, are needed to describe the components and the functionalities of DHT [41]. If medical schools would like their students to be enabled to identify when to deploy DHT and which clinical encounters can benefit from DHT, in-depth understanding of such technologies is required. For instance, why do some activity trackers have a green versus a red optical sensor? It would therefore help the basic or clinical medical sciences faculty to understand photoplethysmography. Moreover, it is important to ensure that DHT is carefully regulated and calibrated to maintain adequate levels of patient safety. This will also raise patient and physician confidence in DHT. All of which will feed into increasing the likelihood of integration of DHT teaching offerings in medical curricula.

Recent research on digital health [33] shows that the following technologies have the most impact on patient outcomes: mobile health, wearables, augmented reality, VR, AI, 3D printing, and drones. Table 4 is an example of a homegrown curriculum [33] which focuses on nurturing among medical students competencies related to such technology, offered in Mohammed Bin Rashid University of Medicine and Health Sciences (MBRU) within Dubai Health in Dubai, United Arab Emirates. It would be recommended that all medical schools teach a similar course in their universities, reinforced by experiential learning in the clinical setting during their placements.

Limitations and future direction

This study is characterized by several limitations including the rapid evolution of this field. Although the selection of universities was performed systematically, it is restricted: high ranking universities may not necessarily be the most advanced in terms of digital health. There could be medical schools which are quite advanced in terms of integrating digital health into their respective curricula but are not top ranked. For instance, an elective course was offered as part of the medical curriculum at Semmelweis University, Budapest, Hungary to enable students in terms of digital literacy, teaching them a broad range of topics including the meaningful utilization of the Internet (within the medical profession), with a special emphasis on social media [42]. Another example is the abovementioned course on DHT and Innovation offered to all first-year medical students at MBRU within Dubai Health in Dubai, United Arab Emirates, through its innovation arm: MBRU Design Lab (Table 4) [33]. The MBRU Design Lab also offers medical students the opportunity to participate in hackathons and bootcamps, where they work with engineering and design students [43]. Due to the young age of the respective university, it currently does not appear as part of the THE ranking. Another example is the University of Bristol in the UK (which narrowly missed inclusion in the study due to ranking at the time of data collection) that designed a Masters dedicated to DHT [44]. The program notably includes classes covering health innovation, epidemiology, AI, computer programming, and data analytics. Moreover, although this study offered plenty of insights, restricting the data source to websites does not allow for developing an understanding of all that is happening on the ground, especially that some university websites may not have been up to date at the time we accessed them. It is possible for the medical schools included in the current study to have, to some extent, DHT integrated in their curricula, while their official websites do not reflect so. For example, the websites may only list the course titles, and/ or not offer any information about corresponding assessments. Some medical schools may teach DHT as part of their Interprofessional Learning (as some DHT may be used by other members of the healthcare team), and hence these courses were not detected in the current study's screening. Similarly, Electronic Health Records

Table 4 Outline of an example of a digital health curriculum, as portrayed in a chapter of the book entitled: Digital health- from assumptions to implementations [33], permission requested from copyright holder

Weeks	Sessions	Description	Learning objectives
1	Digital health	The lecture starts with highlighting the limitations of a non-digital healthcare system. This is followed with the introduction of EMR and continues with the definition of digital health. Some examples of digital health technologies are presented and contrasted with non-digital practices. The lecture ends with the presentation of the key components of a healthcare system and explains the role of DHT.	• Define the concept of Digital Health • Identify the key components of a health system • Understand the status of DHT
2	Persuasive computing and mobile health	The session starts with some facts related to non-communicable diseases and the role the contemporary lifestyle plays in developing those chronic diseases. The BJ Fogg's model, as a simple framework to understand behavioral change, is presented with application examples. The role of mobile devices in behavioral changes is then emphasized. Several examples where digital interventions are delivered through mobile devices are then presented and evaluated. Towards the end of the session, differences between low and high-fidelity digital interventions are discussed.	• Identify what drives behavioral change • Relate to the role of persuasive technology in driving change • Learn why and how mobile devices have empowered patients and medical staff
3	Wearable technologies	The lecture starts with the description of distinct types of wearable technologies and how they can help in better understanding people's Quality of Life. Time is then dedicated to developing a thorough understanding of the characteristics and functionalities of activity trackers, describing how step counting, heart rate monitoring, and energy expenditure are calculated. The limitations of activity trackers are then discussed. The lecture ends with the presentation of use cases where body sensors, smart clothing, smart jewelry, and bio-tattoos are used.	• Describe wearable technology • Explain why wearables are important in supporting people's Quality of Life • Explain the characteristics, benefits, and limitations of wearables
4	Augmented reality and VR	The session starts with a case-study where smart glasses are used to increase the usability and completion of surgical safety checklists in operating theaters. It then continues with defining and contrasting augmented reality and VR. Several case studies where both types of realities are presented, and compared and contrasted, and their benefits and limitations discussed.	• Define the meaning of augmented reality and VR • Describe the benefits and limitations of both technology • Investigate use cases where both technologies are beneficial, and oppositely: are cumbersome
5	AI in medicine	The lecture begins with a discussion regarding the age of AI. It continues with presenting underlying AI concepts from machine learning to deep learning. Then different examples of machine learning are presented, namely supervised and unsupervised algorithms. An example of a supervised algorithm is discussed. From scientific literature, different research is presented highlighting the benefits and the limitations of AI.	• Define the concept of AI and its origins • Explain the role of AI in general and why it is particularly relevant in medicine • Describe the limitations of AI • Analyze successful and less successful eHealth apps relying on AI
6	The future of care delivery	The session starts with describing a typical journey of a patient waiting to visit a general practitioner due to flu symptoms. Using journey mapping, the activities and touchpoints are explained. Then, three DHTs are presented – telehealth, focused on AI-based chatbots; 3D printing; and drones are presented. The benefits and limitations of these three DHTs are discussed. Then, how the journey of the patient will change through introducing the three innovations is discussed.	• Analyze successful and less successful eHealth apps relying on AI • Identify what drones can and cannot do in supporting healthcare • Discuss how 3D printing, another means to deliver care, is changing pharmaceutical business models

may be embedded in a clinical part of the curriculum and not taught as part of a dedicated DHT course. Hence, it would be recommended for future landscape analyses to collect primary data through structured interviews with purposefully selected stakeholders. It is interesting to note that most schools which appeared to be offering DHT classes are postgraduate programs. Yet, most of the schools mentioning 'innovation' in the university and/ or medial program mission statements are undergraduate programs. It would be worthwhile for future studies to investigate the potential contextual enablers (e.g., existence of specific faculty members to teach DHT, national regulatory requirements, and socioeconomic status) for this observation.

Other data sources may include periodic reports and published peer-reviewed articles. In terms of future direction, as well, it would be interesting to longitudinally investigate the association between developing DHT-related competencies and the likelihood of graduates to engage with DHT in their clinical practice. It is worth encouraging medical schools to develop such curriculum-based interventions and run scientific research studies to assess their efficacy and/ or effectiveness, by following a relevant competency framework and including it on their university website.

Conclusion

Throughout the last decade, health care has been disrupted by technology not directly developed for or by medical professionals. The so-called: 'Digital Health Technology' (DHT), has contributed to a customer and technology push that health care was not ready for. The current study suggests that medical schools are not sufficiently contributing to bridging this gap. DHT-related knowledge of medical students is very limited, and they are disappointed by a lack of relevant educational offerings. To the best of the authors' knowledge, this research is unique given that it sheds light on the current state of DHT and innovation teaching of 60 top-ranked medical schools around the world. It contributes to gaining a systemic understanding of where medical schools currently stand when it comes to DHT and also serves as a call for action. The adoption of DHT is growing and the capacity of the technologies is expanding. For instance, the first certified continuous blood pressure monitoring wearable has now reached the market, offering new opportunities to better monitor patients suffering from hypertension. However, as long as physicians' knowledge of the benefits and limitations of this device category is limited, the number of missed opportunities will continue to grow.

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Author contributions
T.B. maintained the macro perspective of the current research study; analyzed the data; and composed the final submission of the manuscript. F.O. analyzed the data; and composed and submitted the final submission of the manuscript. A.B. analyzed the data; and composed the final submission of the manuscript. L.Z. analyzed the data; and composed the final submission of the manuscript. C.K. maintained the macro perspective of the current research study; analyzed the data; and composed and submitted the final submission of the manuscript. All authors approved the final manuscript.

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Data availability
The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approval for the study was granted by the Mohammed Bin Rashid University of Medicine and Health Sciences (MBRU)- Institutional Review Board (IRB) (Reference # MBRU IRB-2024-96). The current study revolved around a systematic analysis of purposefully selected websites and did not involve the recruitment of human subjects, and hence the requirement of consent to participate does not apply.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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