New technological developments in medical education

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Abstract

Introduction: Medical education is a rapidly evolving field, necessitating adaptation to shifts in student demographics and societal needs. Balancing the demand for more healthcare providers must be accompanied by a focus on maintaining the quality of education. As certain conventional teaching methods lose favour, there is a continuous influx of new technologies that can be harnessed for the education of future doctors.

Purpose of the study: The objective of this study was to gather and analyse literature on the utilization of new technologies in medical education and their influence on students, educators, and the overall quality of medical instruction.

Material and methods: A review of the literature available on PubMed and a grey literature search was performed. We used such keywords like: "medical education", "physician training", "medical students", "technology", "elearning", "new learning methods". We also applied Bolean logical operators such as "AND", "OR".

Results: Examining the gathered publications leads to the conclusion that a variety of new technologies are being employed in medical education, such as e-learning, telehealth, and virtual or augmented reality. While some function as alternatives to existing methods, others introduce entirely novel approaches. In general, these new technologies positively impact education by enhancing outcomes, increasing accessibility to education, and reducing the costs associated with the teaching process.

Conclusions: The integration of emerging technologies has become essential in the preparation of future medical professionals. Despite the overall positive impact, there are apprehensions regarding potential long-term consequences for healthcare delivery. Subsequent studies are crucial to assess lasting effects, delving into how the integration of technology may shape the skills of healthcare professionals over time.

Keywords :development of higher education, quality of education, professional education, new technologies, distance educational technologies

Introduction

Medical education understood as acquiring knowledge and psychological/motoric skills necessary for doctors [1], is difficult and a multifaceted problem. Its quality has a huge impact on future health outcomes [2]. In the report prepared by The Institute of Medicine it was pointed that to achieve an improvement in healthcare – to make it safer, more effective, timely, efficient, equitable and patient-centred requires a proper medical education which addresses the needs of the population and is being conducted by properly prepared teachers [3]. Not only the changes in medical education are needed for improvements in quality of healthcare but also because some practises are no longer acceptable for example traditional method of "see one, do one, teach one" raises some ethical issues of learning procedures on a live patient [4]. Another problem with traditional learning is the explosion of medical knowledge – the rapidly increasing knowledge and development of new methods for the diagnosis and the treatment of illness makes it impossible to keep up with all of it [5]. Therefore, there is need to place more focus on teaching about knowledge acquisition and less pure lecture knowledge. Especially since already curriculum in medical schools is overloaded and often it is hard to teach all the required material [6]. Another challenge facing current medical education is the new generations currently entering medical schools who are born into the digital world who are accustomed to technology learning environments the difference between the so-called digital natives and digital immigrants [7]. We cannot also forget that more and more healthcare delivery move from hospital to outpatient setting requiring changes in educational venues [8]. After all it is bet to learn in the environment where later such knowledge will be applied [9] and most of medical graduates end up working in primary care or ambulatory care with focus on people with chronic deasses [8]. The required skills in these different settings are not the same and therefore curriculum should address these differences.

On the other hand, there is a constant call by important stakeholders on more doctors being needed –in Poland Supreme Audit Chamber reported that not only we do not have sufficient number of healthcare providers but also the age structure is problematic [10]. This problem is not limited to Poland but also shared by many other countries both in the European Union [11] or United States of America [12]. This need for more medical doctors is mainly caused by demography – people are living longer, and the society as a whole are aging. In such case it is crucial that people grow older in good health. Despite any attempts to increase the number of healthy life years it is to be expected that the number both - as an absolute value and as a percentage of total population - of people with disability or chronic conditions will

continuously increase, Aging population will also lead to raise in demand for formal care given that the number of informal carers will decrease [11]. The lack of doctors also impacts medical education as it lessens the availability of physicians for teaching but also shows doctors as often harried, overworked, often depressed – which may impact behaviour of future medical doctors [6].

All this leads to uncertainty regarding the future of undergraduate medical education [13,14] These two different needs: for more physicians coupled with a need for change in medical education [2, 6] leads to more widespread use of new technologies. They are often seen as a solution to both these issues. This article will attempt to analyse current knowledge regarding new technologies in medical education – how they influence process of learning, how they are received by both medical students and their teachers and what is their impact on health outcomes.

Methodology

The aim of this study was to analyse the new technologies and their impact on medical education and health outcomes. Our approach adhered to the literature review methodology outlined by Snyder (2019) [15]. The following research questions were formulated:

1. What are the new technologies used in medical education
2. How do they impact medical education
3. How do they impact health outcomes

To address these research questions, we conducted a search between November and December 2023 on PubMed and Google Scholar. We used the search strategy described in table 1

medical education OR physician training OR medical students
AND
Technology OR elearning OR e-learning OR new learning methods

Table 1. Describing search strategy

The inclusion criteria were as followed:

1. The article was published after 2000
2. The paper described new technologies in medical education or its impact
3. Paper was a peer-reviewed empirical study or theoretical paper, technical report, book/chapter, thesis
4. the full text was available in English

Two researchers independently conducted the search process, with each continuing until they perceived saturation of pertinent material. Subsequently, all researchers collectively examined the gathered material, evaluating whether the papers met inclusion criteria and if the collected data was adequate to fulfil the study's objectives. Following the initial search phase, a consensus was reached among all authors that the compiled material was satisfactory. There was no formal grading process.

Furthermore, we conducted a search of non-peer-reviewed literature by examining the websites of various international and national organizations specializing in medical education

In the process of data extraction, two researchers autonomously analyzed materials pertaining to each research question, emphasizing crucial information. They subsequently compared their findings, engaging in discussions to resolve discrepancies and reach a consensus. In cases where consensus could not be attained, a third researcher was consulted for a final decision.

After the completion of the extraction process, all researchers collectively reevaluated the data saturation. Unanimously, they determined that the existing information was sufficient to address the research questions.

New technologies

There are many new technologies and the following list by no mean a full one [4]. They effectiveness varies and different stakeholders not always have the same opinions when it comes to how useful or effective is given technology. According to students – online questions banks, remote progress reviews and telehealth sessions are the most useful methods where for example textbook are assessed as least valuable [16]

E-learning

E-learning also known as online learning or Internet-based learning. There is some discussion regarding the proper definition – some treat e-learning as an umbrella term for two different modes of learning – distance learning and computer-assisted instruction [17]. Distance learning is using technology to allow access to lecture by students who are at a different location. In case of computer-assisted instruction the learning process is based on using a stand-alone multimedia package for learning [18]. However, another classification separates e-learning, online learning and distance learning as 3 different definitions [19] – distance learning being based on that some form of instruction occurs between two parties but not at

the same time and/or place. In such classification e-learning is learning *using technological tools that are either web-based, web-distributed, or web-capable* [19]. Finally online learning is defined as *access to learning experiences via the use of some technology [*19]. To simplify in the following parts of article we will use the first classification.

One of the most often pointed out advantage of e-learning is increased accessibility to information [17]. Such characteristic was especially advantageous during the covid pandemic when the changing situation forced medical faculties to quickly change the learning and examination method [20-21]. In such case it should be no surprise that eLearning was recognized as a solution especially since it has already started gaining traction as a recognized teaching method [22-23]. Because of that adaptation to covid pandemic provides us with good opportunity to analyse the effectiveness of eLearning and how it was received by medical students and educators. Many universities moved to holding lectures either synchronously live streaming session or prerecorded sessions, with the first option being much more popular [24]. It allowed to conduct lectures and continue education despite the lockdowns and obligatory isolation. Even now – after most or even all of the limitations connected with covid-19 has been lifted many universities kept some of the changes introduced to pandemic – for example by continuing to hold lectures online or in hybrid form. Despite there are many opinions regarding this form of teaching.

When it comes to student perspective they mentioned many advantages such as time-saving, timetable flexibility, it is more comfortable, allows to cut costs, reduces anxiety . On the other hand many respondents in questionnaires regarding learning pointed out to low quality of teaching and poor interactions with teachers. Distance learning is also characterised by a couple of challenges for students unique to this mode of learning – problems with internet coverage, limitations in data packages, variation in education platforms, family distraction and lack of space [25]. Despite the fact that many medical students were unsatisfied with eLearning provided during pandemic they had overall positive attitude towards this mode of learning [26]. However is important to note that medical students reported that such learning does not allow to obtain practical clinical skills with losing live experiences with patients and families being noted as one of the biggest drawbacks of online learning. Additionally, some students miss the challenge of quick thinking and learning under pressure – which is a must in many clinical settings [16].

E-exams

The rapid evolution of remote exams, also known as e-exams, amid the COVID-19 pandemic and the surge in e-learning represents a significant transformation in medical education. Recognized as a key component of distance learning [27], the manner in which e-exams are conducted and their impact on both students and faculty is a crucial aspect of assessing new technologies in medical education.

Several challenges need to be adressed before effective online assessments can be implemented. Common issues shared across all degrees include concerns about cheating [28]. However, medical education presents unique challenges, such as the ability to accurately grade practical skills and ensuring that graduates are well-prepared to function as competent healthcare professionals [29]. In a 2020 study by Elsalem et al. [30], 34% of students reported that remote and in-person exams induced similar stress levels, while 33.6% found remote exams to be more stressful. Technical factors, such as concerns about internet connection stability and issues related to the examination platform, significantly contributed to the heightened stress associated with e-exams. The unfamiliarity with this examination format may also explain why it was perceived as more stressful by a considerable portion of respondents [31].

Additionally, both students and faculty expressed concerns about the potential for dishonesty in remote exams. However, the implementation of student authentication systems also emerged as a stress-inducing factor for some students [32]. Balancing the need for exam security with the potential stressors associated with authentication procedures is a complex aspect that requires careful consideration in the ongoing development of remote exam practices in medical education.

Virtual wards rounds

Beside holding lectures via videoconferencing or by providing prerecorded video many universities provided also other way of teaching. In some cases, they used virtual wards round to educate students regarding covid-19 cases [33] or by live streaming operations to the students [34]. Using streaming from operation enabled students to watch from home various operations allowing to continue surgical rotations despite being at home with surgeon being able to communicate with students via internet. By live-streaming students could interact with the surgeon which is a huge advantage over watching prerecorded video.

Telehealth

Other method of teaching students during covid-19 pandemic was engaging them in telehealth [35]. This is especially interesting as little is formally taught about telehealth despite the fact it is becoming bigger and bigger aspect of modern healthcare delivery [36].

Telehealth or ehealth is understood *as an umbrella term for the use of information and communication technologies in health-related services and processes* [37]. It therefore includes things from electronic health records to telemedicine services [38]. There is hope that ehealth has the potential to improve the quality of medical care, reduce length of hospitalisation and lower the overall costs of healthcare [37]. It has also a potential to have a huge impact on medical services in rural area due to increasing the access to specialist care without the need for long trave [39] However once again to realize that objectives there is need to introduce proper changes in curriculum of medical schools [40]. This is especially important since current predictions are that ehealth will reach nearly 100% penetration of healthcare sector [36]. Despite the proficiency of most medical students in new technologies, assuming that they can deliver high-quality telemedical care without proper training is unrealistic. Many physicians highlight the lack of adequate training as a primary barrier to incorporating ehealth practices into their own medical practices [41]. The technological limitations, including variations in the data available to doctors, such as the absence of information from physical examinations, necessitate a shift in the diagnostic process [42]. Physicians must possess the ability to discern when telemedicine is appropriate and when an in-person consultation is necessary. Telemedicine is also a quickly evolving field – both when it comes to available technologies but also when it comes to regulations. Integrating telemedical training into curriculum of medical school will allow the future doctors to learn best practices and being able to recognize when each method is better. Additionally, evidence suggests that incorporating telemedicine into the curriculum enhances the development of core competencies in patient care and practice-based learning [43]. This advantage is likely attributed to the ability to review a large number of high-yield cases with attending physicians in a short period. While there is limited number of evidence regarding the training in telemedicine [44], it is a quickly growing field of research with proposed models for incorporation [42,44]. The consensus among experts is that telemedicine training should be integrated into existing parts of the curriculum to prevent overburdening students [43]. This approach ensures that future healthcare professionals are well-prepared to navigate the dynamic landscape of telemedicine and contribute effectively to evolving healthcare practices.

Example of such a solution can be found in change in internal medicine clerkship during covid-19 pandemic [45]. In this program students had to complete American College of Physicians online learning modules on telemedicine. Afterwards they took part in orientation meeting hosted by faculty members. They were taught about opportunities for patient assessment, overall concept of telehealth and the model of care delivery via a video platform. Afterwards they were assigned to a resident or an attending doctor working in general medicine and ambulatory practice. Students at first were responsible for more technical side of the visit (helping set up the meeting) but with gaining experience they were also conducing initial screening and televist wrap-up. Students taking part in this course found that during the televists they covered wide-range of cases including both acute care and chronic diseases. This form of training allowed them to improve their communication skills, especially empathy during videoconference. Students reported that after such clerkship they were able to build relationship with the patient especially if the patient in question had more than one visit. Therefore, one of the most common fears stopping doctors from participating in telehealth was addressed and solved.

Another technology making strides in the field of medical education is immersive technology, specifically virtual reality (VR) and augmented reality (AR) utilized as instructional tools. VR constitutes a computer simulation enabling users to completely immerse themselves and engage with a synthetic environment [46]. Conversely, AR is an interactive technology overlaying holographic content onto the user's real-world environment [47].

The consensus among medical educators is that medical instruction should actively engage students rather than relegating them to passive roles in the learning process [48]. While simulation medicine is not a novel concept, it has continuously evolved over the past four decades [49]. Research indicates that simulations offer a more effective learning approach compared to traditional methods like lectures and seminars [50].

Virtual reality

Virtual reality allowed to host a simulation of bedside teaching even during the pandemic. When asked students responded that using vr to share cases in paediatrics [51] was more effective than lectures, reading from books or seminars. However, 80% of the respondents said that VR was less effective than bedside teaching. Teaching using VR was shown to improve competency confidence levels and greater information retention [52, 53].

Additionally, VR was shown to be a good way to improve visual spatial ability which is especially useful during minimally invasive procedures. When compared groups of trainees who finished VR course compared to those who did not intervention group was shown to have better results – not only in surgical performance but also in completion time [54]. Learning using virtual reality was also shown to cultivate nontechnical skills such as situation judgement therefore allowing attaining higher level of surgical competencies earlier [53]. Additionally, virtual environments are shown to be a safe space to explore complex scenarios [55] which coupled with the fact that learning sessions are recorded allows to easily review the training by teacher or by both teacher and the student and learn by making mistakes. Virtual reality was also shown to be quite cost-effective learning tools as headset can give access to several students [56] which coupled with the fact that it allows to rise of teacher to student ratio [53] shows that it would be a worthy investment for university. There is also hope that teaching using virtual reality will allow to democratize access to high quality training by helping connecting specialist with smaller centres [53].

Studies have also demonstrated that virtual reality can serve as a viable substitute for cadaver training, even for surgical residents [57]. This shift offers numerous advantages, including improved training accessibility as there is no longer a need to source cadavers or maintain them under specific conditions. Virtual reality simulation devices are reusable, eliminating the need for an on-site instructor. Furthermore, virtual reality training is inherently safer for the trainee, practically eliminating the risk of disease transmission.

Despite cadaver training being traditionally considered the gold standard, research indicates no statistically significant differences in safety or economic outcomes when comparing groups trained in arthroscopy for shoulder surgery using cadavers versus those trained with virtual reality. Similar to earlier studies, trainees instructed through virtual reality were faster in acquiring skills compared to those undergoing traditional training methods [57].

Given the substantial practical training required in surgery, integrating virtual reality training proves to be an effective strategy in expediting the readiness of surgical residents, particularly in situations where the availability of cadavers is limited [58].

The safe environment offered by virtual reality for teaching practical skills and permitting the learning from mistakes represents a promising avenue for the field of emergency medicine and other high-acuity departments. In the evolving landscape of emergency medicine departments and intensive care units, where there is a growing emphasis on fostering a safety

culture and heightened oversight, opportunities for students and residents to engage in experiential training are diminishing. This trend raises concerns about the potential inadequacy of their preparedness for independent action upon graduation [59,60].

Simulation-based training in medicine offers a safe learning environment; however, it is often associated with high costs and operational complexities [61]. Consequently, there is a rising focus on training through virtual reality. Many experts assert that despite its inherent drawbacks and limitations, virtual reality provides a valuable simulation experience for managing emergency patients [62]. Given that the skill sets required in emergency scenarios differ from those typically analysed, such as the aforementioned surgical simulations that concentrate on technical skills, there is optimism that virtual reality will emerge as a pivotal modality for future training in almost all fields of clincal medicine.

Overall, the COVID-19 pandemic expedited the transition from conventional simulation medicine to virtual reality, necessitated by unforeseen circumstances [63]. However, despite this shift, there is insufficient evidence to conclusively determine whether virtual reality can entirely replace traditional simulation in undergraduate medical education [64]. Existing studies on this topic vary in methodological quality, posing limitations on synthesis and making it challenging to draw universally applicable conclusions [64].

Nevertheless, a general trend from these studies suggests that virtual reality performs favourably when compared to traditional simulation across metrics such as medical knowledge scores, cognitive gains, skill performance scores, and skill success rates. It's important to note that these outcomes may be influenced by how the assessments are conducted – whether they are based on virtual reality assignments or traditional simulations [65]. Despite the limitations and weaknesses inherent in individual studies, a collective examination of the research leads to the conclusion that virtual reality stands as a valuable tool for enhancing medical knowledge and its practical application, with outcomes at least comparable to those observed in traditional simulation settings [64].

Augmented reality

While there are many possible uses for augmented reality in medicine one of the most popular is using head-up displays during surgery. It was shown to improve surgeon operating experience by allowing for better visualization of operated vessels, improved ergonomics and timesaving [66]. It also can be used for better monitoring of surgical trainees by observing the undergoing procedures by a remote party with quicker consultation [67].

Conclusion

The COVID-19 pandemic has had a profound impact on various aspects of life, prompting a swift transition to remote learning in medical education, akin to many other higher education fields. This sudden shift expedited the ongoing process of digitizing medical education, with emerging technologies now playing a crucial role in preparing future medical professionals. While the overall impact of this transformation is predominantly positive, there are lingering concerns regarding potential long-term consequences on healthcare delivery.

To comprehensively understand the enduring effects of this change, there is a pressing need for more extensive studies, particularly those conducted over an extended period with robust methodologies. These studies should analyze how the integration of technology into medical education may influence the skills, approaches, and perspectives of healthcare professionals in the future. By addressing these concerns through rigorous research, we can gain a better understanding of the potential challenges and benefits associated with the digitalization of medical education. This ensures that the evolution of medical training aligns with the overarching goals of enhancing patient care and healthcare delivery.

Disclosure
Supplementary materials

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Authors contribution:

Conceptualization, Beniamin Michalik and Katarzyna Hajduk-Maślak methodology, Beniamin Michalik; software, Aleksandra Szypuła; check, Michał Sęk, Iwona Galasińska and Adrianna Skóra; formal analysis, Michał Sęk and Beniamin Michalik; investigation, Adrianna Skóra, Beniamin Michalik, Katarzyna Hajduk-Maślak resources, Aleksandra Szypuła; data curation, Adrianna Skóra; writing - rough preparation, Iwona Galasińska; writing - review and editing,Adrianna Skóra; visualization, Katarzyna Hajduk-Maślak supervision, Beniamin Michalik; project administration, Iwona Galasińska; All authors have read and agreed with the published version of the manuscript.

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