Medical Science Educator (2020) 30:1707–1720
https://doi.org/10.1007/s40670-020-01040-w

REVIEW

Perception of Technology-Enhanced Learning by Medical Students: an Integrative Review

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Published online: 10 August 2020

Abstract
This review aims to explore the perception of technology-enhanced learning by medical students. From the initial 2947 records found, 38 studies from journals indexed in the Web of Science database were included after screening. Several main topics were isolated, based on a thematic analysis: student's attitude towards e-learning and modern technologies in medical education; social networks, video, and mobile devices as information source and communication tool; and barriers to the use of technologies in medical education. The results have shown that a positive attitude towards technologies in medical education and learning is prevalent among students. The popularity of blended learning was confirmed.

Keywords Technology-enhanced learning · Medical education · Perception · Awareness · Medical students

Introduction

Technology, which inherently enters every area of life in the twenty-first century, can make it easier to gain access to higher education and lifelong learning [1]. Technology-enhanced learning (TEL), which can be defined as the implementation of information and communication technology (ICT) into teaching and learning [2], is a common occurrence for today's students. One area of specialized education strongly influenced by technological development is medical education [3]. The overall technological development and the effect of digitalization and the Internet inevitably bring new demands and requirements on the denizens of the twenty-first century [4]. New types of literacy, such as Internet, media, information, or ICT literacy, have appeared.

We can see a substantive shift in the approach to teaching and learning in medical disciplines. As a result, these disciplines are now at the forefront of implementation of cutting-edge technology into their curricula [5, 6]. Along with the entrance of digital technology into higher medical education, we are now witnessing an increased focus on student-centered learning [7], blended learning [8], or the flipped classroom model [9]. An Internet connection enables immediate access to clinical information, medical applications, and scientific periodicals, from inside the ward and clinical environment both [10]. Literature also indicates that mobile devices [11], virtual reality (VR) [12], and video [13] play a role in medical education as well.

Background

Up-and-coming medical professionals will belong to generations (such as Generation Z), for whom it's typical to be always online, to commonly use smart phones and social networking pages, and share not only information but emotions as well. They can be described as advanced users of digital technology [14]. Their medical practice will be strongly influenced by omnipresent digitalization and, among other things, electronic health records (EHR) will be a common occurrence [15]. Even though the students of the current generation were born into the age of Internet and digital technology, it does not mean they will all take an absolutely positive stand towards them, with no reservations [16]. Literature appears to move away from the term "digital natives"—people with an automatic affinity for digital technology [17]—and towards a new term—digital learners—thus rejecting generational borders and their predefined properties [18, 19]. Despite these facts, a clear trend in medical education can be observed—"student-driven learning with advanced technology" [20]. For

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stakeholders—specifically medical faculties and teachers themselves—to efficiently design technology-driven teaching methods, they have to adhere to "learner-centered design" principles and consider "learner experiences with educational technology" as a key factor in learning environments development [21]. One of the key components of learning experience is learners' perception (formed during their "…interaction with a learning environment…"), usually followed by students' "actions, attitudes, and emotional experiences" [21]. Perception is an integral part of a framework called the 3P model of learning, which illustrates the process of knowledge creation in higher education environments [22–24]. The framework helps us to better conceptualize the factors that influence students' task performance (learning outcomes). This model has been developed and modified continually since the end of the 1970s [25]. 3P in the model's name stand for "Presage" ("characteristics of the student" and "course and departmental learning context"), "Process" ("students' perceptions of context" and "students' approaches to learning"), and "Product" ("students' learning outcomes") [24]. Perception in the Process phase is defined as "students' perceptions of context (e.g., good teaching, clear goals)" [24]. The 3P model has gradually developed into the 4P model, where Perception is set aside and acts as a moderating factor in the relationship between the Presage and Process phases [26]. Price [27] states that "...students' perceptions and their conceptions of learning and teachers' perceptions and their conceptions of teaching are important elements related to the whole concept of improving student learning." Educational technologies have entered teaching and learning processes in medical education and they are here to stay. More than ever before, it is now important to focus on research into students' perceptions of learning environments, so that strategic decisions about curriculum changes at medical faculties (based on the implementation of new technology) are empirically well-grounded. Information gained from this kind of research can be used to identify favored technologies, in order to implement them in teaching, and also to predict their usefulness in the future. This can help teachers and lecturers to simplify the choice of appropriate technologies for specific classes. At the level of departments and faculties, this can also serve as evidence-based foundation for conceptual decisions concerning TEL [28].

The Review

Aim

The goal of this integrative review is to find an answer to the research question below by synthesis of published relevant studies.

Research question: How do students in medical disciplines perceive TEL (technology-enhanced learning)?

Design

An integrative review was chosen because it allows the processing and incorporation of studies with varying methodologies (quantitative, qualitative, experimental, or non-experimental), for the ultimate purpose of gaining the most complex understanding of a given phenomenon possible [29]. This review was created based on the methodology described by Toronto [30] and, among others, Robin Whittemore and Kathleen Knafl [29]. The process includes identification of problem, publication search, data evaluation and analysis, and presentation of results.

Search Methods

For the purposes of this study, the database Web of Science (WoS) was chosen as a source for publication search, and this particular database was chosen because, in the academic community, it is generally regarded as the best source for only the highest rated studies that adhere to the strictest measures of quality.

The search itself was conducted in the middle of April, 2020, with the use of key words, such as *perception*, *awareness*, *experience*, *perspective*, *attitude*, *e-learning*, *blended learning*, *ICT-enhanced learning*, *technology-enhanced learning, ICT*, *information and communication technology*, *medical*, *learner* and *student*. To capture the most up-to-date publications, the year of publication range was limited to 2015–2020 (by April 15, 2020).

Search Outcomes

Out of the initial 2947 publications, 1113 were remaining after filtering based on various categories, such as language, year of publication, and document type. One of the exclusion criteria was also the focus on pharmacy, dentistry, nursing, paramedical, or other allied health professions in the literature. After reading their titles and abstracts, a final number of 38 articles remained, having met the requirements of the research question above. These articles were chosen for this review (for more details about this process, see the flow diagram of study selection in Fig. 1).

Data Analysis

Based on a thematic analysis, codes have been created and grouped into categories and broader topics. After reading through the papers, a manual analysis was conducted utilizing a pen-and-paper-based method. From the analysis, three main topics have emerged: students' attitude towards e-learning and

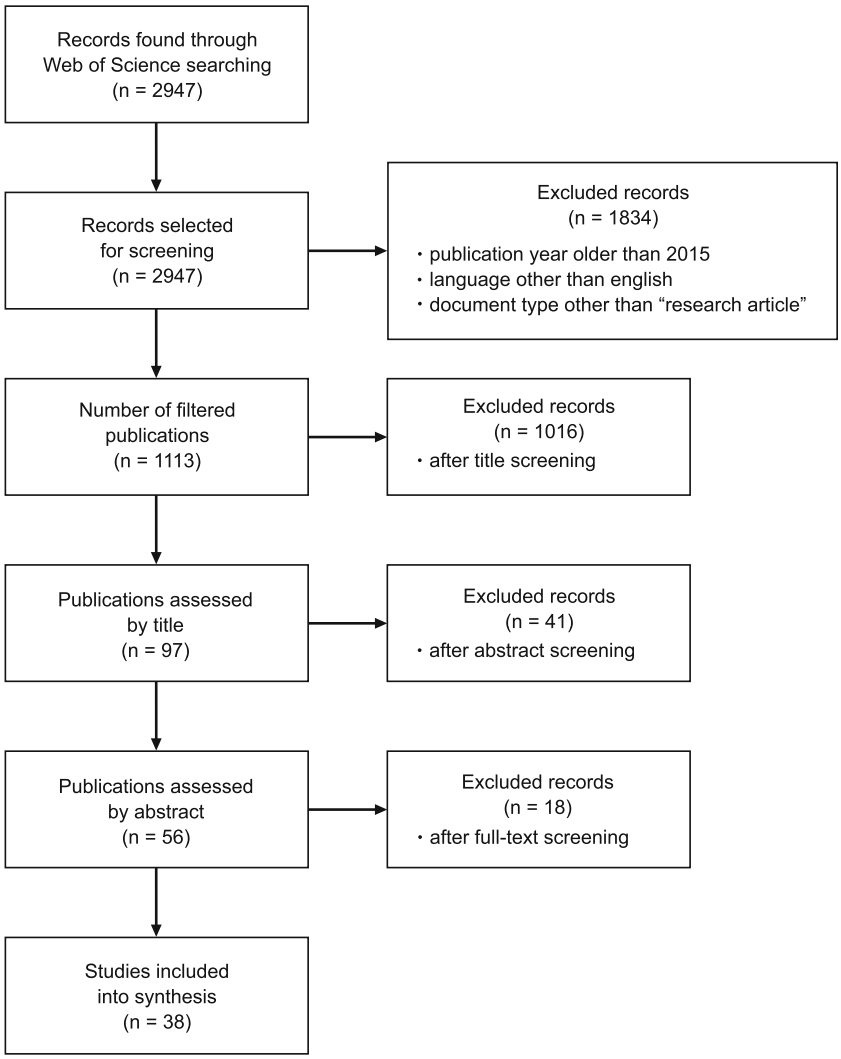

Fig. 1 Flow diagram of study selection

modern technology in medical education; social networks, video, and mobile devices as an information source and communication tool; and barriers to the use of technology in medical education.

Data Appraisal

Thirty-eight studies were included in the integrative review, 4 of them experimental, 7 qualitative, 18 quantitative, and 9 utilizing mixed method research (Table 1). Data appraisal was conducted using the Critical Appraisal Skills Programme (CASP) Qualitative Research Checklist for qualitative studies [31] and Mixed Method Appraisal Tool (MMAT) version 2018 for quantitative and mixed method research [32]. The scale for paper quality assessment was adopted from Andrew and O'Doherty [33, 34], with the following outcome: Quantitative and mixed method studies were rated between excellent, good, satisfactory, and poor; qualitative studies between low, medium, and high. None of the qualitative studies was evaluated as low quality; in the case of quantitative and mixed methods studies, none of them was found poor or satisfactory. None of the final 38 studies was disqualified because of improper methodology.

Results

Study Characteristics

Studies used for this review were published between 2015 and 2020 in peer-reviewed periodicals. Their research samples comprised of medical students, with the exception of Barry [35], who studied a combination of medical students and radiation therapy students. Thematic analysis has resulted in three final areas: (1) students' attitude towards e-learning and modern technology in medical education; (2) social networks, video, and mobile devices as an information source and communication tool; and (3) barriers to the use of technology in medical education.

Table 1 Included studies

Citation	Journal	Research design	Data collection	Sample	Aim of study	Location
Selzer et al. (2015)	*Medical Teacher*	Qualitative	Focus groups	17 medical students	"To develop a near-patient e-learning tool and explore student views on how utilization of such a tool influenced their learning."	Australia
Stankovic et al. (2015)	*Acta Facultatis Medicae Naissensis*	Quantitative	Survey	371 medical students	"…to analyze attitudes and knowledge about distance learning of medical students, as well as to determine the influence of gender and age."	Serbia
Woodham et al. (2015)	*Journal of Medical Internet Research*	Quantitative	Survey	119 medical students	"…to explore how undergraduate medical students interpreted and evaluated information from video- and text-based materials presented in the context of a branched interactive online virtual patient designed for PBL." (problem-based learning)	UK
Alnabelsi et al. (2015)	*European Archives of Oto-Rhino-Laryngology*	Experimental	Pre-test and post-test	50 medical students	"…to assess and compare FtF teaching with SeL in the context of otolaryngology undergraduate training using teaching on otolaryngology emergencies as an educational intervention."	UK
Back et al. (2016)	*International Journal of Medical Education*	Quantitative	Survey	505 medial students	"To investigate medical students' utilization of and problems with a learning management system and its e-learning tools as well as their expectations on future developments."	Germany
Creutzfeldt et al. (2016)	*Jmir Serious Games*	Qualitative	Focus group	12 medical students	"…to reach a better understanding of the learners' reactions and experiences when using an multiplayer virtual world (MVW) for team training of cardiopulmonary resuscitation (CPR)."	Sweden
Sattar et al. (2016)	*Biomedical Research-India*	Quantitative	Survey	432 medical students	"…to evaluate the medical students' opinion on the using of social networking sites and learning and development of medical information."	Saudi Arabia
Sandholzer et al. (2016)	*European Journal of General Practice*	Quantitative	Survey	305 medical students	"To explore medical students' perceptions regarding the potential of a general practice app for training and subsequent work as a physician."	Germany
Lehmann et al. (2016)	*Annals of Anatomy-Anatomischer Anzeiger*	Quantitative	Survey	175 medical students	To investigate "...whether a video-based blended learning approach is well accepted and perceived as being effective for real pediatric patient encounters at the bedside, and how its curricular implementation can be optimized."	Germany
Al-Hussaini and Tomkinson (2016)	*Journal of Visual Communication In Medicine*	Qualitative	Focus groups	30 medical students	"…to evaluate the potential educational value of using an iBook to supplement ENT undergraduate teaching."	UK
Barry et al. (2016)	*Anatomical Sciences Education*	Quantitative	Survey	73 medical and radiation therapy students	Attempt…"to gauge the attitudes of anatomy students to the use of social media in the context of the blended learning approaches in anatomy."	Ireland
Sezer (2016)	*Computers In Human Behavior*	Mixed	Survey and focus groups	414 medical students (survey) and 12 medical students (focus groups)	Mapping…"medical students' attitudes towards e-learning."	Turkey
Jamal et al. (2016)	*Jmir Mhealth And Uhealth*	Quantitative	Survey	133 residents	"…to evaluate the prevalence of mobile phone usage among medical residents and to explore their attitudes, perceptions,	Saudi Arabia

Table 1 (continued)

Citation	Journal	Research design	Data collection	Sample	Aim of study	Location
					and the challenges they experience when using mobile phones in academic and clinical practice."	
Tummons et al. (2016)	*Higher Education Research & Development*	Qualitative	Ethnography	Canadian university—two campuses	Seeking…"to contrast dominant, institutional discourses of technology use in higher education teaching with the everyday practices of staff and students."	Canada
Liebert et al. (2016)	*Surgery*	Mixed	Survey (open questions)	89 medical students	Investigation of…"medical students' perceptions of a simulation-based, flipped classroom for the surgery clerkship, and suggests best practices for implementation in this setting."	USA
Ekenze et al. (2017)	*World Journal of Surgery*	Quantitative	Survey	291 medical students	Evaluation of…"the medical students' knowledge and use of Internet tools, and their opinion on the application of these tools in surgical education."	Nigeria
Pickering and Bickerdike (2017)	*Anatomical Sciences Education*	Mixed	Survey and Facebook analytics	156 medical students	To explore…"how a Facebook Page could support Year 2 medical (MBChB) students in preparation for summative anatomy assessments and alleviate test anxiety."	UK
Stepan et al. (2017)	*International Forum of Allergy & Rhinology*	Experimental	Pre-intervention, post-intervention and retention quiz	66 medical students	"…evaluate the effectiveness, satisfaction and motivation associated with immersive VR simulation in teaching neuroanatomy."	USA
Prakash et al. (2017)	*BMC Medical Education*	Quantitative	Survey	94 medical students	To analyze…"the perceptions of medical students towards short-duration podcasts."	India
Briz-Ponce et al. (2017)	*Computers In Human Behavior*	Quantitative	Survey	160 medical students	To analyze…"the factors that affect the students' behavior towards the use of mobile technologies."	Spain
Mogali et al. (2018)	*Anatomical Sciences Education*	Mixed	Focus groups and survey	15 medical students	"…to examine the educational value of the 3DP model from the learner's point of view."	Singapore
Fernando and Lindley (2018)	*Journal of The American Medical Informatics Association*	Qualitative	Case study	15 medical students	Reporting on…"the development and delivery of an mHealth elective piloted for first-year undergraduate medical students at Monash University (Australia) and the lessons learned by designers."	Australia
Milic et al. (2018)	*Plos One*	Quantitative	Survey	1110 medical students	To report on…"the results of a pilot study aimed at developing, implementing and evaluating the course 'Applicative Use of Information and Communication Technologies (ICT) in Medicine' upon medical school entry."	Serbia
Harrington (2018)	*Journal of Surgical Education*	Experimental	Question banks and survey	40 medical students	To…"Describe the production of a high quality 360° video for an index-operation (augmented with educational material), while evaluating for variances in attentiveness, information retention, and appraisal compared to 2D."	Ireland
Chase et al. (2018)	*BMC Medical Education*	Mixed	Survey and free text data analysis	275 and 217 medical students	"To assess the impact of mLearning devices in the clinical learning environment on medical students' studying habits, attitudes towards mobile device supported learning; and the perceived reaction of clinicians and patients to the use of these devices as part of learning in the clinical setting."	UK
Scott et al.(2018)	*Clinical Teacher*	Mixed	Learning analytics and questionnaire	98 and 146 medical students	"…to document the learning habits of contemporary medical students during a clinical rotation by exploring	Australia

Table 1 (continued)

Citation	Journal	Research design	Data collection	Sample	Aim of study	Location
					the use of locally and externally developed digital and print self-directed learning resources, and study groups."	
Khamis et al. (2018)	*Medical Teacher*	Quantitative	Survey	176 medical students	"To compare IT skills, uses and preferences for education between traditional and PBL medical students."	Saudi Arabia
Virtanen et al. (2018)	*Journal of Histotechnology*	Quasi-experimental	Electronic questionnaire	57 medical students	To assess…"students' perceptions of a ubiquitous 360° learning environment (ULE) in histotechnology comparing ULE perceptions to conventional web-based learning environment (WLE)."	Finland
Law et al. (2018)	*The American Journal of Surgery*	Quantitative	Survey	125 medical students	To examine…"the types of technology used by medical students in clinical clerkships, and the perception of technology implementation into the curriculum."	USA
Pedersen (2018)	*Academic Psychiatry*	Qualitative	Six group interviews	30 medical students	"…to explore medical students' learning experiences from the didactic teaching formats using either text-based patient cases or video-based patient cases with similar content."	Denmark
Cheng et al.(2018)	*Applied Clinical Informatics*	Quantitative	Survey	94 medical students pre-commencement and 87 post-commencement survey	"…to quantitatively characterize medical students' expectations and experiences of an electronic health record (EHR) system in a hospital setting, and to examine perceived and actual impacts on learning."	Australia
Waseem et al. (2019)	*Pakistan Journal Of Medical & Health Sciences*	Quantitative	Survey	135 medical students	"To evaluate student perceptions regarding use of social networking sites…"	Pakistan
Naseem et al. (2019)	*Journal of The Pakistan Medical Association*	Mixed	Questionnaires and focus groups	275 medical students survey and 16 medical students focus groups	"To identify perceptions of key stakeholders in a private medical college for the adoption of technology-enhanced learning at the undergraduate level."	Pakistan
Lowell and Alshammari (2019)	*Educational Technology Research And Development*	Mixed	Six perceived learning surveys	23 medical students	"… to evaluate the perceived learning benefits of completing experiential learning activities in a virtual environment…"	USA
Hyll et al. (2019)	*BMC Medical Education*	Qualitative	Semi-structured interview	15 medical students	"...to explore students' learning experiences while using a Prezi presentation in the context of learning antibiotics."	Sweden
Holland and Pawlikowska (2019)	*Anatomical Sciences Education*	Mixed	Survey and free text comments analysis	313 medical students	To examine "…student usage and perceptions regarding case-based learning activities, provided in both face-to-face and eLearning formats…"	Ireland
Chen et al. (2020)	*Advances In Physiology Education*	Quantitative	Survey	173 medical students	"To explore students' perceptions of whether blended laboratory courses are helpful for them in overcoming the difficulties they experience."	China
Brockman et al. (2020)	*Medical Education Online*	Quantitative	Survey	247 medical student	"…to examine students' perceptions of online and in-person microbiology lab learning experiences."	USA

Students' Attitude Towards e-Learning and Modern Technology in Medical Education

The first topic, common for 20 studies, was students' attitude towards e-learning and modern technology.

According to Sezer [36], there is no connection between the grade in which the students currently are and their attitude towards e-learning. Rather, the students' academic achievement has been found to have a significant influence on their perception of e-learning, wherein students with more success tend to regard e-learning more positively.

According to the Serbian study, e-learning is not pushing out classic teaching methods, but rather serves as their supplement. The study also found that 85% of the students (out of 371) knew what distance learning was, regardless of age or gender. Gender differences appear to play a role in attitudes towards distance learning. A larger percentage of women believed that distance learning helps with faster memorization of the topic. On the other hand, male recipients did not report a significant difference in knowledge gains between classic lectures and distance learning. However, they do find the flexible access to materials to be an advantage of e-learning [37].

With regard to learning styles, Brockman [38] states that students, who studied using online materials, preferred visual style, whereas participants of a lab class in person favored contact teaching.

In a Nigerian study, more than a half of the participating students (out of 227 in total) strongly agreed that the tools and opportunities of the Internet can be used in surgical education [39]. As typical examples, the students have mentioned videos of procedures and images of interesting cases. A total of 67% of students were of the opinion that using only traditional methods for training in surgical education—without Internet tools—is insufficient to adequately prepare them for practice.

At the University of Sydney, the majority of students (74 out of 98) were using electronic materials created in other institutions but also considered those created at their own university to be beneficial for their learning [40].

Chen [41] states that 75.14% of students (out of 173) confirmed the increase in their learning motivation, thanks to blended learning laboratory courses. Seventy-one percent of them also reported a better understanding of key concepts and theories.

A similar study conducted at the University of Belgrade Faculty of Medicine, focused on mapping students' attitudes towards ICT, has stated that the students consider blended learning to be the ideal way of learning, as it connects easy accessibility of learning materials with time flexibility [42]. From the total of 1110 students, 80% stated that students of medicine in general need ICT, while 83% consider ICT to be useful for physicians. The majority of the students also agreed with the statement that computers make everyday life easier.

According to the findings of Hyll [43], a presentation created in the online service Prezi makes for a flexible learning environment, which improves the students' learning process engagement. However, students themselves considered it to be only a supplementary tool.

An iBook with otolaryngology study texts was viewed as a valuable learning material, with a structure suitable for students [44].

An American study concerning the use of technologies in clinical clerkship has shown that only 2 students out of 125 would prefer electronic materials and distance learning exclusively. The majority of students (53.6%) would like to frequently use various technologies during class, such as online lecture notes, PowerPoint presentations, and audio/video streaming. Three-quarters of the students agreed that they would prefer in-person classes, as opposed to a form of distance learning [45].

A study dealing with electronic health records (EHR) has confirmed that students feel competent in their computer literacy skills and have no trouble learning, how to work with new software. They presumed that learning to work with EHR would be simple. The students did neither expect nor experience any negative influence of EHR on their interaction with patients. An educational potential of EHR for prescribing medication or placing orders was not proven [46].

A study dealing with simulation teaching with the use of the flipped classroom method has shown an overwhelmingly positive student feedback—90% (out of 77 total respondents). Students consider simulations to be an excellent teaching/learning element: 87% of them evaluated home preparation like this, while real-time use of simulations during class was appreciated by 98% of them [47].

An experiment was conducted to compare two groups of students with different tools available to them during class. One made use of virtual reality, and the other had web-based textbooks and 2D materials. No differences between learning outcomes of these two groups were proven. However, VR was perceived to be more captivating, more popular, and more useful compared with web-based textbooks and 2D image materials [48].

The participants of another experiment were divided into two groups: one attended a classic style lecture (in otolaryngology) in a lecture hall and the other attended a webinar. After pre-test and post-test assessment, both groups showed comparable improvement in knowledge acquired. The difference in perception of the form of learning was not significant between these groups. Overall satisfaction with the class was, however, lower in the webinar group [49].

While comparing case-based learning activities provided in both face-to-face and e-learning formats, Holland and Pawlikowska [50] have found that learning enjoyment feedback was more positive for e-learning attendants, but the students chose to discuss their experience in person, rather than in the online environment.

Another type of study, conducted at Lee Kong Chian School in Singapore, has compared students' perception of two types of anatomical models: 3D-printed models vs. plastinated specimen (models created by a conservation method that replaces water and fats in real tissue with specialized plastic, preventing biological decomposition). This study confirmed students' positive view of 3D models, highlighting their accuracy and benefit towards learning. However, the vast majority of students also stated that the 3D models are not as faithful as the plastinated specimen, and they would welcome the use of both types of models during class [51].

According to Lowell [52], a 3D environment is beneficial for students and the additional employment of role-playing is an effective method for the development of mental health interviewing and diagnosis skills.

In the case of cardiopulmonary resuscitation (CPR) training using a multiplayer virtual world, a Swedish study has confirmed that this activity was engaging for the participants, and it helped them clarify the procedures involved in CPR. However, they described the scenario as lacking in realism, because of its absence of hands-on experience with providing CPR, as well as psychological pressure, which would be present in a real situation. Controlling the simulation (especially the avatar) proved to be problematic for students, who lacked prior deeper experience with videogames, whereas experienced videogame players criticized the interface more [53].

The use of video in teaching, being technologically more advanced and more difficult to implement, was described in a study comparing 360-degree video with classic 2D format. The researchers found out that the technologically more advanced form of video (3D, 360-degree) does not surpass the classic 2D form in terms of better learning retention. However, during their observation of the 3D, 360-degree variant, the students felt completely focused and described this form as more fun and literally mesmerizing [54].

A histotechnology class at the University of Applied Sciences in Helsinki, set in a ubiquitous 360° learning environment, was rated extraordinarily positively by students [55]. The perception of a class in a conventional web-based learning environment was equally positive, with regard to flexibility, content awareness, and interactivity. The quasi-experiment also confirmed that both learning environments had an overall positive influence on students, who were engaged and shared enthusiasm for the use of modern technology. Students taking part in the ubiquitous 360° learning environment reported the experience as more challenging than the conventional web-based learning control group.

Social Networks, Video, and Mobile Devices as Information Source and Communication Tool

The topic information source and communication tool was found in another group of studies.

Pickering and Bickerdike [56] have mapped the use of Facebook pages for study purposes. According to the students (119 users of this web service), Facebook is an effective complement for their studies and exam preparations (85%). They stated that it helped reduce their anxiety before exams and helped boost self-confidence (73.2%). The majority of the students (85.7%) have visited the page 2–3 times a week.

In a Pakistani study, the data clearly shows that the vast majority of students (92% out of 135) considered social media to be an indispensable part of today's life, as well as a simple tool for quick acquisition of medical information [57]. This conclusion is fully corroborated by Sattar [58], who adds that social networking software provides opportunities for the promotion of medical activities and ultimately leads to an improvement in communication in health care in general.

According to Barry [35], the majority of students (78% of 73) used YouTube videos, and when they needed to solve a difficulty encountered in their anatomy learning, they looked for correct answers on web-based platforms (62%) and/or social media websites (10%).

A video instruction manual for the examination of pediatric patients was perceived positively, as a means to prepare for medical practice and OSCE (objective structure clinical examination), and was overall a worthwhile learning experience for students, according to a German study [59]. Thanks to these videos, the students felt more confident during bedside teaching.

Another study dealing with video learning material was published by Woodham [60]. While some students considered video to be a benefit regarding problem-based learning, they still mostly preferred text. This was because video causes a slowdown in critical situation assessment, and so the students regarded it as supplementary material suited for filling in details.

Pedersen's study [61] has confirmed that students, who attended psychiatry classes grounded in video-based patient cases, put stronger emphasis on patient perspectives, compared with students, who participated in text-based patient case classes. Video has proven to be better suited for the support and development of students' "patient-centeredness."

In the area of audio-documents, an Indian study has shown that short podcasts can be viewed as a useful complementary tool to help students prepare for exams [62].

An Australian study dealing with the development and implementation of web-based e-learning tool for mobile devices, while focused on patient-centered learning and just-in-time learning, points out how positively the tool was perceived by students [63]. Students stated that thanks to this application, they get immediate access to tailor-made learning materials which they can study ahead of time, based on patient diagnosis. This preparation for meeting with the patient boosts their self-confidence during the meeting itself and helps inform the following treatment procedures. The students

preferred to use mobile devices as opposed to hand-written notes in paper notebooks, which need to be checked in printed publications.

Another study has addressed students' views of general practice textbooks in the form of mobile applications. 57.4% of the students (out of 305) considered these applications to have a larger potential for education, while 47.1% of them believed these apps would be useful for their future physician practice—specifically for looking up information, diagnosis, therapy and prediction, and also to access electronic files, communication, and networking [64].

According to Khamis [65], the majority of students (out of 176 responding) prefer mobile devices and a moderate amount of IT in education. Fourth and fifth year medical students mostly regarded various online tools as beneficial for education—namely Google (94.2% and 86.7%), YouTube (90.7% and 92.2%), and PubMed database (83.7% and 86.7%).

Most of the 160 participants (94%) of a Spanish study stated that the use of mobile devices was simple, but only 39% of them considered these devices to be useful. Only 13% of the students agreed that adequate external support was provided, while only 10% of theme considered the facilitating conditions to be satisfactory. Almost one-quarter (24%) of the students were ready to do homework on mobile devices, while 50% trusted them and would recommend them for study purposes [66].

The majority of respondents of a study conducted in Saudi Arabia (82 out of 92) also stated that they consider smartphones a useful tool for communication between employees in a hospital, whereas only 35 of them consider them to be useful for communication with patients' family members. Only a very small number of respondents have attended any course focused on the work with mobile devices. Between men and women, no differences in the use of mobile devices were found [67].

Barriers to the Use of Technology in Medical Education

The last identified topics are perceived negatives of and barriers to the use of technology in medical education.

Even though the Pakistani study found the students to be digitally literate and commonly in use of digital technology, it also identified a key challenge: to map the teachers' skills and abilities to incorporate such technologies in teaching. As the greatest barrier to the use of technology, the study has identified the teachers' lack of time and opportunity to learn to utilize them, exacerbated by additional factors, mainly generally weak support on the side of faculties, poor technical support, and lack of access to modern technologies themselves [68].

According to the students from Charité – Universitätsmedizin Berlin, the greatest weakness lies in insufficient integration of e-learning into classes (58.7% out of 505). Even though the students mostly found such technologies easy to use (92.5%), more than one-fifth of them have also mentioned technical difficulties of some kind [69]. Mobile technologies have a clear barrier in problematic Internet access, but also the fact that students tend to use them for leisure activities, rather than for clinical learning [70].

A case study focused on an undergraduate elective program at Monash University in Australia, relating to Mobile health (mHealth—providing medical services via mobile devices), has shown that even though students are used to using smartphones for communication, social networking, and university LMS (learning management system), they still lack sufficient ICT terminology and are unable to assess medical applications [71]. At a Canadian university, researchers have attempted to connect classes in two different campuses. From the bigger campus (designated as main), where classes took place, lectures were video-transmitted to the smaller (satellite) one, from where students had the opportunity to ask questions. The biggest challenge was the preparation of the lecturer for this kind of lecture, which comprised of organizing discussion in both campuses at the same time, by controlling movement within a specified sector to ensure optimal camera capture etc. [72].

Discussion

Students' Attitude Towards e-Learning and Modern Technology in Medical Education

The results included in this integrative review have confirmed that students of medical disciplines perceive technology-enhanced learning as an attractive complement of education. Most commonly, they consider the function of technologies to be an information medium for learning, and also a communication medium. Even though generally positive attitudes towards technology are prevalent, certain barriers have been identified, e.g., insufficient ICT literacy or ICT as a disruptive element.

The experimental study with students of otorhinolaryngology has shown differences between attendees of a webinar and students, who attended face-to-face teaching classes, with the former group demonstrating lower levels of satisfaction with the class [49]. Compared with students from an in-person lab class, participants of an online microbiology lab class were more surprised by the contents of a quiz, as they encountered what they perceived as previously undiscussed topics [38]. In the case of clinical clerkship, students favored in-person classes as well [45]. Additionally, Davis [73] also argues in favor of traditional classes in small groups. However, this claim cannot be generalized. According to an

extensive systematic review conducted at the Imperial College of London in cooperation with WHO, there can be no certainty that traditional teaching methods are any better or worse than e-learning with regard to knowledge and skills acquisition. The attitude of students towards e-learning seems inconclusive as well [74]. Women seemed to view e-learning more favorably than men [75], while seeing a larger learning potential in distance learning, especially regarding subject matter retention and information sharing between colleagues [37]. However, this is not always the case. A study of dental students has not proven gender to be a relevant factor in attitudes towards e-learning [76]. Similarly, Mohammed [77] has found no measurable influence of gender on e-learning readiness.

On the other hand, students see the tools and capabilities of the Internet as uniquely fitting for surgical education [39], and blended learning courses ensure flexible access to teaching materials [42]. Likewise, blended learning laboratory courses cause an increase in students' learning motivation and improve their analytical reasoning skills [41].

These conclusions correspond with other literature that focuses on popularity of blended learning in general [78–80], digital self-directed learning resources [40], and other electronic information sources [44]. The entry of additional technologies into the learning process, namely EHR, does not cause a disruption in the student-patient interaction [46]. Yet students still consider technology to be a supplementary, rather than a pivotal part of learning [43, 73].

Blended learning in the form of the flipped classroom method, focused on simulation teaching, has reached notable popularity among students [47], as well as CPR practice via multiplayer virtual worlds [53], or mental health interviewing in a 3D environment with role-playing elements [52].

A positive attitude towards simulation-based teaching is proven by other literature as well [81, 82]. On a similar note, case-based learning activities provided in e-learning format have earned notable popularity among students [50]. Students also tend to prefer web-based simulations to learning from traditional textbooks [83]. Other positively perceived technologies, such as VR [48], 3D video [54], 3D-printed anatomical models [51], and histotechnology in a ubiquitous 360° learning environment [55], were assessed very positively by students. However, the question remains, whether the costs of purchasing and implementing these hi-end technologies, specifically VR and 3D video, can be justified, as the abovementioned studies imply that the technologies' positive influence on students' learning outcomes is not guaranteed. In many countries, acquiring human cadavers and organs is, often for religious and cultural reasons, difficult [84]. This might be an opportunity for 3D printing, as this technology can already create life-like high-fidelity anatomical models [85]. In the case of VR use, health risks have to be taken into account as well, as cases of nausea, vertigo [86], and motion sickness [87] have been recorded.

Social Networks, Video, and Mobile Devices as an Information and Communication Tool

This topic has turned up repeatedly in the included studies, especially those focused on mobile devices, social networks, and video. Two studies included in this integrative review note that social networks, as well as short podcasts, can play a supportive role to students' preparation for exams [56, 59]. The literature also implies that social networks are indeed environments which support learning in general [88], learner engagement [89], and motivation to self-study and class engagement [90]. For medical students, mobile devices have become a natural part of life, convenient for acquiring and sharing medical information [64, 65]. They view them as useful, both during practice and real-life clinical settings [63, 91], and they find their usage to be simple [66]. Students also appreciate them for enabling access to electronic medical records [92], Google, YouTube, and PubMed database [65], and more convenient finding of drug information [93]. Positives are perceived in the area of communication with colleagues (classmates) or superiors [67] as well.

Students also have a positive view of work with medical apps [94]; however, if they are offered a wide range of different medical apps by their institution, they only tend to use a select few [92]. For instance, an application that compiles course-specified information sources was appreciated more as a textbook, and the students would have liked to continue using it during their future physician practice [64]. This can be an incentive for university libraries to increase their effort in providing mobile application education [93].

With respect to anatomical courses, students highlight mostly the use of videos [95], which they prefer to be as detailed and abundant as possible [96]. This corresponds with the findings of an integrative review concerning the popularity of anatomical videos published on YouTube [35]. Video is mostly suitable for clinical skills training [97] and pediatric patient examination training [59]. Using video in courses based on patient cases has also proven to be an efficient tool for students' empathy development [61].

The limits of video usage have, however, manifested clearly in the case of problem-based learning, where video turned out to be less suitable than textual materials containing information about virtual patients [60].

Barriers to the Use of Technology in Medical Education

Even though students view work with mobile technologies as efficient [70], mobile phones can become a disruptive element for them. Almost 50% of them admitted to using mobile phones for making calls or writing text messages during a patient examination, while 30% stated that they can be a distraction even during class [91]. This unwanted side effect of

mobile devices was confirmed in other studies as well, labeling the iPhone as a distractor during class [98, 99]. Insufficient ICT literacy was identified as another commonly occurring problem [71]. Other notable barriers include problems with universal Internet access [70], Wi-Fi connection [100, 92], ignorance of quality information sources and how to work with them, and technical issues [69, 93].

Barriers in the use of ICT in education are known even among educators—insufficient ICT skills, not enough time, problems with infrastructure in a given institution, problems in the general attitude of involved parties and mistakes in their communication [34, 68].

Study Limitations

It is necessary to point out the limitations of this study, mainly the categories which originate in a thematic analysis and the interpretation of the perception of TEL by medical students. The categories are not necessarily completely exhaustive and thus may not encompass all outlooks, attitudes, approaches, and perceptions concerning TEL in medical education. Despite the effort to capture all variations of key words in the research, the nature of the search queries may have caused some relevant literature to be omitted, because the key words did not appear in either the paper title or its abstract. Possible relevant papers published in journals not indexed by WoS have not been included in the review. This also applies to unpublished documents and other forms of gray literature.

Suggestions for Further Research

A follow-up study could be focusing on emotions, specifically on the way in which emotions enter into TEL, and how they can influence learning outcomes of medical students. In order to create a more comprehensive representation of educational technologies in teaching and learning processes, the perspective of the teachers needs to be explored as well. A potential new research could focus on the topic of "how do medical educators and faculties perceive TEL?"

Conclusion

This review has focused on students of medical disciplines and their perception of technology-enhanced learning. The results have shown the extensive nature of the topic, with a wide range of varied studies already published. The students' attitudes range from very positive responses, defining ICT as a tool for reinforcing subject matter, an effective communication instrument, and an attractive and entertaining class component, to more negative opinions, putting technology in the role of a mere supplement to face-to-face learning. The positive part of the feedback to methods and contents of lectures that use technology exists in no small part thanks to teachers, IT specialists, and technicians, whose efforts make this learning style possible. For future betterment of teaching (and learning) with the use of technologies at medical faculties, a few recommendations have been derived: the continuous increase of teachers' IT literacy, support, and promotion of M-learning (learning with the use of mobile devices), and last but not least promotion of university LMS and video in education. Another opportunity is in a tighter integration of social media (incl. YouTube) into blended learning courses. Today's generation of students, accustomed to social networks in every area of everyday life, could learn in an environment and with the tools they are familiar with. Mandatory courses in information and computer literacy could smoothen the journey through studies for new coming students as well.

Availability of Data and Materials All data generated or analyzed during this study is included in this published article except for the complete database search string, which is available on request.

Compliance with Ethical Standards

Conflict of Interest The author declares that he has no conflict of interest.

Abbreviations 2D, two-dimensional space; 3D, three-dimensional space; CASP, Critical Appraisal Skills Programme; CPR, cardiopulmonary resuscitation; EHR, electronic health records; ICT, information and communication technology; IT, information technology; LMS, learning management system; mHealth, Mobile Health; M-learning, mobile learning; MMAT, Mixed Method Appraisal Tool; TEL, technology-enhanced learning; VR, virtual reality; WoS, Web of Science

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