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Review

Trauma Care Training in Vietnam: Narrative Scoping Review

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Abstract

Background: The model of trauma in Vietnam has changed significantly over the last decade and requires reforming medical education to deal with new circumstances. Our aim is to evaluate this transition regarding the new target by analyzing trauma and the medical training system as a whole.

Objective: This study aimed to establish if medical training in the developing country of Vietnam has adapted to the new disease pattern of road trauma emerging in its economy.

Methods: A review was performed of Vietnamese medical school, Ministry of Health, and Ministry of Education and Training literature on trauma education. The review process and final review paper were prepared following the guidelines on scoping reviews and using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart.

Results: The current trauma training at the undergraduate level is minimal and involves less than 5% of the total credit. At the postgraduate level, only the specialties of surgery and anesthesia have a significant and increasing trauma training component ranging from 8% to 22% in the content. Trauma training, which focuses on practical skills, accounts for 31% and 32% of the training time of orientation courses for young doctors in “basic surgery” and “basic anesthesia,” respectively. Other relevant short course trainings, such as continuing medical education, in trauma are available, but they vary in topics, facilitators, participants, and formats.

Conclusions: Medical training in Vietnam has not adapted to the new emerging disease pattern of road trauma. In the interim, the implementation of short courses, such as basic trauma life support and primary trauma care, can be considered as an appropriate method to compensate for the insufficient competency-related trauma care among health care workers while waiting for the effectiveness of medical training reformation.

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KEYWORDS

trauma training; Vietnamese medical education system; medical curricula; short course

Introduction

Over the last 2 decades, there has been a sharp increase in private vehicle use in Vietnam consequential to economic and transport infrastructure development. From 2006 to 2018, the number of cars and motorcycles increased by 413% and 317%, respectively, to more than 3.9 and 58 million, respectively [1,2]. Consequently, the number of road accidents has risen in parallel with the number of cases, increasing from approximately 11,000 in 2009 to a peak of 43,000 in 2011 [1]. The latest figure (1st quarter of 2021) witnessed an improvement but was still an alarming number with 3206 cases involving around 1672 deaths and 2386 injuries [3]. Due to the prevalence of motorcycle

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transport, not surprisingly, head injuries accounted for more than three-quarters (79%) of road trauma injury (RTI) cases presenting to the emergency department, followed by multitrauma (9.2%) and limb injuries (2.3%) [4]. Trauma is always on the list of the leading causes of mortality and morbidity in all age groups and worldwide [5]. Despite the enforcement of wearing helmets on motorcycles in 2007 [6] and legislation adjustment for drunk driving in 2020 [7], along with HIV/AIDS, RTI is a health burden in Vietnam [3,8,9]. This is because, like other low- and middle-income countries (LMICs), the prehospital care system in Vietnam is underdeveloped. Consequently, 42% of RTI victims died before reaching a health care facility compared with 29% in hospitals [10].

In the Vietnamese health care setting, trauma victims will generally be taken to the grassroot-level center, such as a district or provincial hospital, for initial treatment. However, the health workforce, especially physicians in these settings, mainly consists of general practitioners and nurses who are varied in their level of trauma training. Only 1.7% of health staff in these facilities have specialty training (including trauma specialists) [11]. "Trauma doctors," as they are referred to in Vietnam, are specialized in trauma care and have been trained in a postgraduate program. They tend to be located in large central health care centers rather than in rural or provincial areas [12]. Consequently, serious trauma patients need to be transferred from commune health stations and district hospitals to a higher-level care facility where there are doctors specialized in trauma care. It has been estimated that 55% of trauma victims present to provincial hospitals, so it can be seen that these centers need trauma training at least to the level of stabilizing patients before transfer [4].

Since the reunification of the country in 1975, the medical education system has been community-based to address a shortage of human resources in Vietnam and to distribute them more equitably. This model, however, has restricted the time exposed to specialist training, including training at both undergraduate and postgraduate levels [13,14]. Nevertheless, medical training, in general, must be adapted to the epidemiologic transition of an emerging economy in which road trauma is a major burden for the health care system. A review in 2012 by Fan et al documented medical training in Vietnam to that date [13], but information regarding the content of training concerning the burden of disease was not well ascertained. Since then, there have been changes in regulations and curricula in most medical universities. This article aims to review how trauma care training is provided in Vietnam and to explore the pattern of such training programs and courses.

Methods

Study Design

This was a narrative scoping review [15]. Since there is a lack of a review on trauma care training in Vietnam and the scope of the research question is broad, a scoping review combined with narrative synthesis was deemed to be the most appropriate method [15]. The scoping review design allows us to identify broad and diverse types of trauma care training. A narrative synthesis provides a context in which to describe what is deficient and necessary to address for different participants (ie, trainees). Information for this study was identified, extracted, and charted from various sources, including international and domestically published studies, as well as the gray literature. The review process and final review paper were prepared following the guidelines on scoping reviews [16] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [17].

Eligibility Criteria

Eligible articles/reports for this study were publications that reviewed or reported information concerning the trauma care training in Vietnam. As we also analyzed the content of trauma care training in medical training, the curriculum from medical universities was also included. Papers that reported trauma care training for non-Vietnamese health care workers, not working in the Vietnamese health care system (eg, training for US medics and nurses during the Vietnam War) were excluded.

Information Sources

We conducted a systematic search for peer-reviewed articles in the English language, which were indexed in the MEDLINE database (through PubMed) in February 2021. We also searched domestic literature through electronic databases at Hanoi Medical University (HMU) and Vietnamese Joint Medical Library [18]. Furthermore, gray literature was identified through an online search via Google Scholar and the websites of major medical universities in Vietnam, Vietnamese Government agencies, and nongovernment organizations.

Search

The search strategy in PubMed was developed to include studies with the following terms in the title/abstract: "Vietnam" OR "Viet Nam" AND "trauma" together with "training" OR "education" OR "continued medical education" OR "CME." The details of the search strategy are provided in Multimedia Appendix 1. Meanwhile, the search in the aforementioned Vietnamese sources was performed with equivalent keywords in the Vietnamese language such as " (trauma)" and " (training)."

Selection of Sources of Evidence

Two reviewers (BTN and TLP) independently selected studies. Any discrepancy in the selection was solved by a discussion with a third reviewer.

Data Charting Process

Key findings from documents in the Vietnamese language were summarized and translated into English. Two reviewers (BTN and THHK) independently extracted data from the included studies and reports using a standardized data extraction form. The extracted information included the year of publication, type of training (undergraduate, postgraduate, and continuing medical education [CME]), number of credits, duration of training, etc. Any disagreement in data extraction between the 2 reviewers was resolved by discussion with a third-party reviewer (TLP, VATN, and HTN).

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Synthesis of the Results

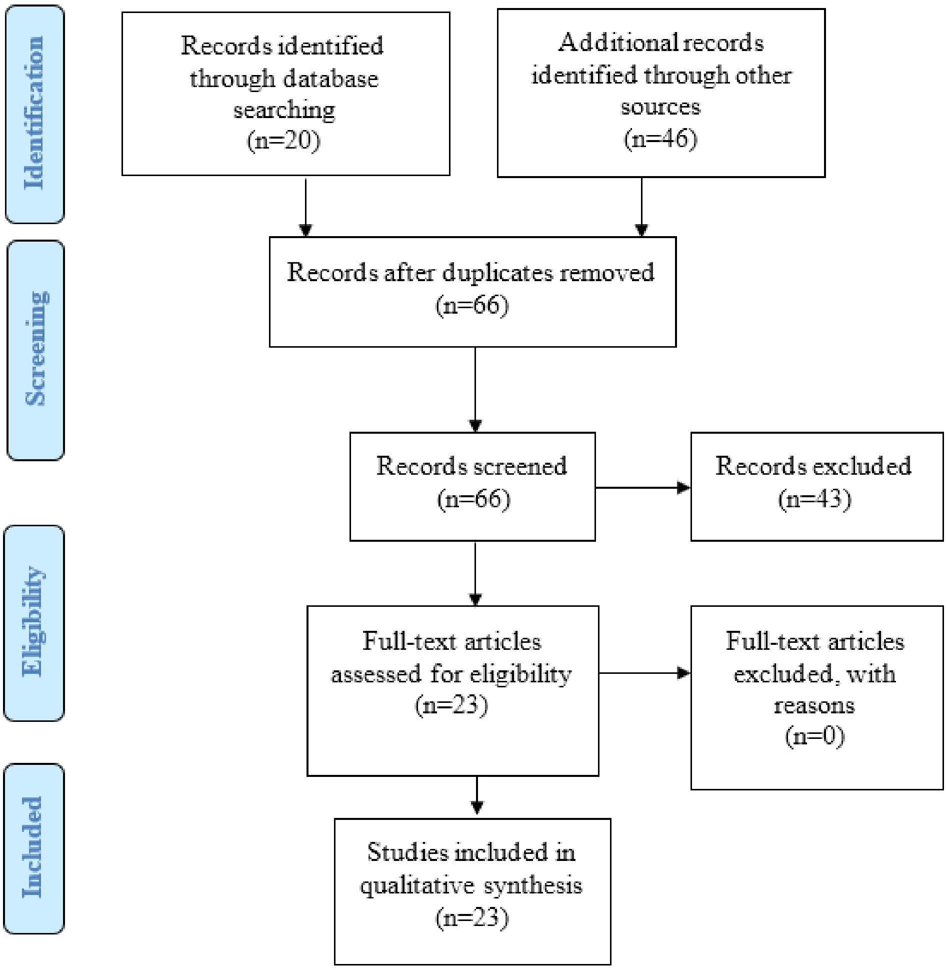
The results were narratively summarized. We further analyzed the curriculum of the undergraduate and postgraduate programs of HMU, as an example, to illustrate the duration of trauma training. The selection of HMU as the showcase is justifiable since HMU is one of the top medical universities in the country and has been assigned by the Ministry of Health (MOH) to develop the training outputs standard for general doctors.

Results

Search Results

Our search strategy identified 2 English language articles/reports and 2 Vietnamese language research articles/reports that met the eligibility criteria. We also included 19 gray literature documents (Figure 1). Our literature search did not identify any review articles.

Figure 1. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart.



Undergraduate Training

In 2021, there were 27 medical universities in Vietnam, with the public sector dominating the private and with most of the sites located in urban areas [19,20]. For undergraduate training, the following 2 health care worker training programs currently exist in Vietnam: a 6-year program (doctor training) and a 4-year program (nurse and medical technician training). Each medical university built its curriculum based on the framework curriculum, which was developed and approved by the MOH and the Ministry of Education and Training. The university must have received approval from the MOH before delivering its curriculum [21,22]. This research only describes the curriculum of the 6-year program (general doctor training program).

The undergraduate curriculum consists of about 60 subjects, which can be combined into the following 3 categories: basic science, preclinical, and clinical. The curriculum structure is almost identical in all the medical universities and has not changed much in recent years [13]. However, the trauma training theme only accounts for a few lessons in the following 6 subjects: nursing, preclinical, anesthesia, basic surgery, pathological surgery, and surgery (Figure 2).

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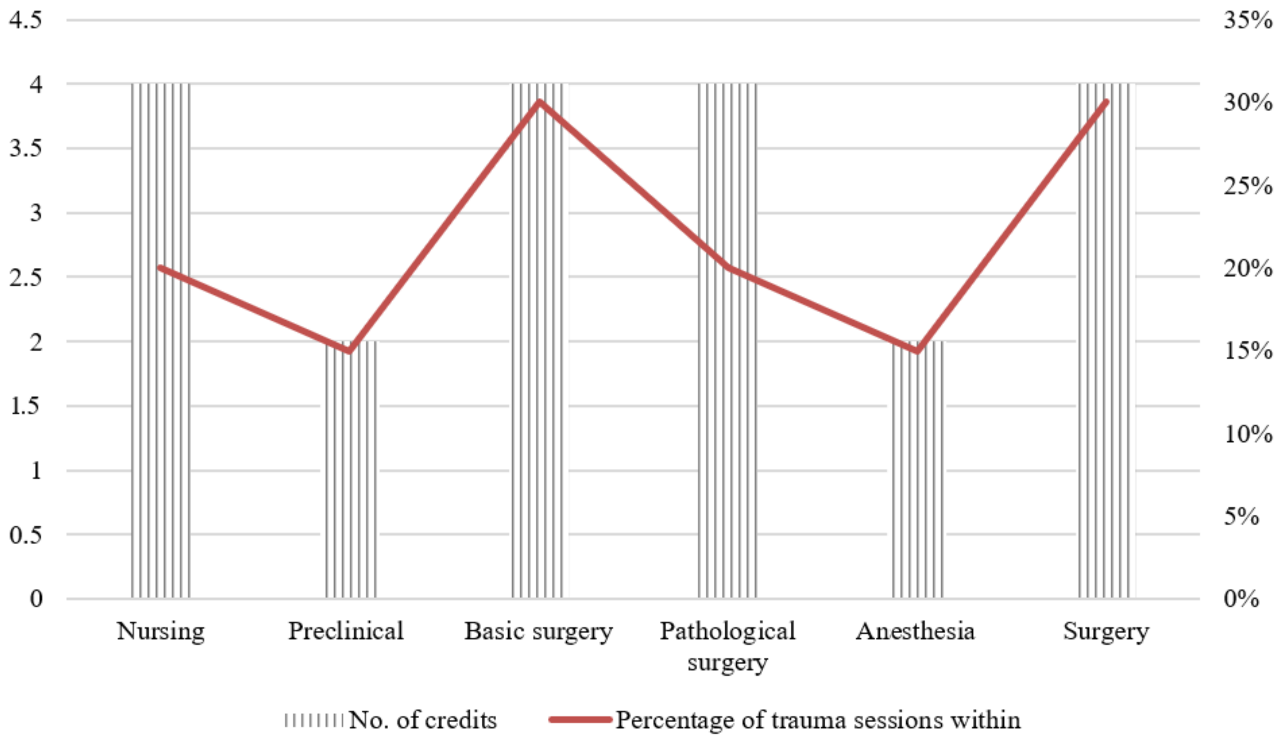
Figure 2. Trauma-related lessons by subject in the curriculum of Hanoi Medical University.



Trauma lectures appear from the second to the final year of the medical training program (Figure 2). Clinical case testing occurs when students complete their hospital rotation, and then, students are assessed for theory by a multiple-choice examination. Every medical student must complete both theory and practice components with 233 credits in total (each credit is equivalent to 15 lessons, and each lesson is 45 minutes of teaching) during the 6 years at the university to become a doctor [23]. Of these, only about 10 credits have content relating to trauma or first aid training (under 5%). The content of the lessons is varied with more than 40 different tasks such as skills of surgical abdominal examination, clavicle and femur immobilization skills, and skills of examination and first aid for abdominal injuries. To evaluate the academic results, each student takes a clinical-based assessment and multiple-choice question (MCQ) theoretical examination on a computer. In the final year, the content on surgery relating to trauma care is separated into small parts in 10 lessons.

Many students return to local health centers to start working at a commune or at district health facilities right after graduation. First aid and trauma care skills taught at the undergraduate level, therefore, are extremely important for them. However, the current medical training program does not focus on preferential or targeted first aid training for this group of students.

Postgraduate Training

After completing 6 years of study at a medical university, students have the following 2 main choices: participate in postgraduate training programs immediately (residency training) or practice at the hospital for 18 to 24 months to gain experience and receive a medical practicing license. The license is a prerequisite of some postgraduate training programs (specialized level I [SL-I] and master's degrees). There are the following types of postgraduate training in Vietnam: clinical training (practice doctor, SL-I, and specialized level II [SL-II]), academic training (master and PhD), and residency training. In all types, the trainees will choose a specific specialized training program (internal medicine, surgery, etc). These forms of training differ in training duration, entry criteria, and output standards. Specifically, the SL-I, SL-II, and master training programs take 2 years, while this duration is 3 years for residency training and from 3 to 7 years for a PhD program. Students have to satisfy the criteria of having 2 to 3 years of experience in the applied specialty and to pass an entrance exam to be eligible for the postgraduate training, except PhD candidates who have distinct requirements. To complete the programs, most of the trainees have to defend their thesis prior to graduation, which will be assessed internally by professors [24], except the SL-I program, for which the trainees only have to pass the final test that normally involves MCQ and clinical-based assessments.

As for residency training, students need to finish both dissertation and graduation examinations [25,26]. The residency training in Vietnam involves both the academic and clinical sectors. As a result, after completing this program, trainees can gain both a master's degree and residency certification. With these qualifications, graduated resident doctors may be eligible for higher education enrolment in either an academic (PhD) or clinical field (SL-II).

The curricula of all training types follow a unified system that is developed by the MOH. The training content includes basic science subjects, basic medicine groups, foreign languages, and specialty subjects. The duration of subjects is the same across majors, except for specialty subjects. Moreover, there are 27 different medical majors in Vietnam, but no separate major specialized in trauma.

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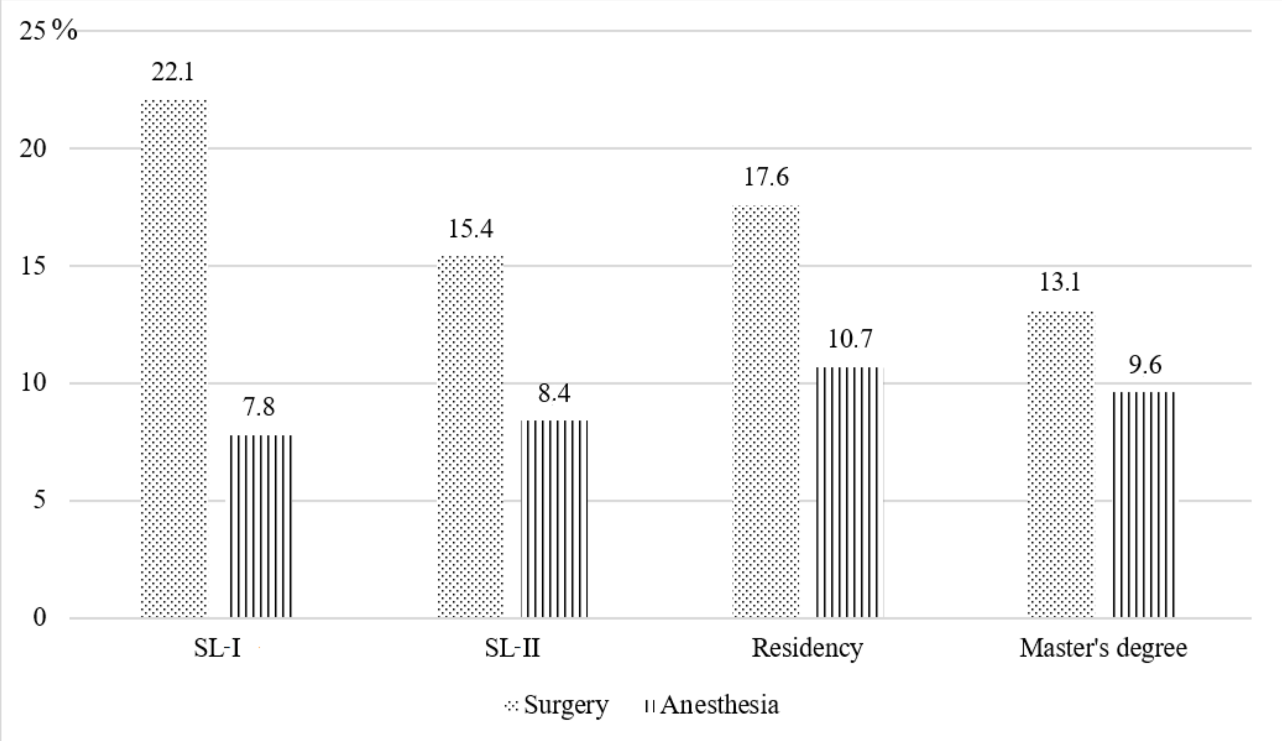
Like the undergraduate program, there is no trauma specialist training in these upper levels, with 2 postgraduate programs that are partially related to trauma care including surgery and anesthesia. However, by analyzing the curricula of these programs, the proportion of formal sessions directly related to trauma care ranged from 13% to 22%. The figure for the latter was even lower at approximately 8% to 11% (Figure 3). The first aid and trauma lessons included such topics as airway management, polytrauma management, and brain trauma resuscitation. Lessons may be theoretical, practical, or both. Of those with both components, practice dominated theory. Unlike the other training streams, doctoral training does not require any course component [27-33]. Most of the theory content is taught to students face to face in class, while the teaching method for the practical component varies from skill stations and clinical scenarios to "bedside learning" in real patients.

Figure 3. Percentage of lessons related to trauma in 2 postgraduate programs. SL-I: specialized level I; SL-II: specialized level II.



CME, Orientation, and Short-Course Training

Orientation or Basic Course

After graduation from medical school, generalist doctors can choose to go directly to clinical practice in primary health care or pursue an orientation course with a duration of 6 to 11 months in a specialty such as surgery, emergency medicine, or internal medicine. There is no entrance examination for the orientation course. This course is a requirement in addition to evidence of 18 months of hospital practice for medical license approval (specialist).

During their training time, trainees need to pass MCQ and clinical-based assessments. After completing the course, they qualify as a "practice doctor." However, this type of training has been terminated by the MOH since 2019 [34]. After this date, all specialties have created another "basic course." These courses have a similar structure of training to other specialized "orientation courses." Of those, the 2 majors most relevant to trauma training are "basic surgery" and "basic anesthesia," with 31% and 32% trauma training content, respectively [35,36]. Both courses emphasize on practice rather than theory only, as the former dominates the latter regarding training time [35,36]. The 2 programs are considered as the first step of the specialty training process, so they have been designed to equip participants with basic rather than advanced skills. As a result, after graduation, a program participant is likely to be adequately trained at the grassroots level in the health care system.

CME and Short-Course Training

Like other countries, participation in CME and short-course training in Vietnam is mandatory for doctors to be able to register and maintain their medical license. The CME and short-course training could be organized by a medical school, hospital, or specialized medical association such as the Vietnamese Association of Traumatology and Orthopedics. Therefore, these training courses are varied in their topics, durations, trainers, and trainees.

The main purpose of these courses is to provide front-line health workers with knowledge and skills to deliver emergency medical care with only basic equipment and facilities. The format of courses is varied (1- to 3-day courses). The number of participants is also different between courses [37,38]. Most participants are doctors (surgeons, general practitioners, and anesthetists) and nurses, but there are some paramedic staff.

Some courses have received very positive feedback from participants. One hundred and eighty medical staff participated in Luong's study about capacity building [37]. Over 90% of them assessed the training program as suitable between the

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objectives with the theoretical and practical content. These courses are truly global, and the momentum seems to keep going in this direction. Over 1200 cases received first aid by participants with almost 100% rated as good management (airway and circulation management, limb fixation, and hemostasis). Another report by Nguyen concerned capacity improvement courses for lower-level injury in emergency facilities, which were conducted in 2016 with 220 medical staff [38]. The number of trainees with good first aid/trauma skills also increased markedly after completing these courses. The percentage of trainees who had good performance was over 80%. Therefore, the number of patients who needed to be transferred to a higher-level hospital subsequently decreased significantly.

Furthermore, Choi et al conducted a study on the outcome of a trauma education workshop in Vietnam [39]. The participants were highly satisfied with the quality of the workshop content (mean score 4.32, SD 0.62; measured by a 5-point Likert scale). The mean score of the teaching skill satisfaction and the perceived benefit from the workshop were both over 4 out of 5 points [39]. These types of evaluations have low face validity and reinforce the need for prospective studies looking at trainee knowledge and practice and patient clinical outcomes.

There are many short courses on first aid training in Vietnam annually. However, after completion, few courses reported course effectiveness, highlights, or learner feedback. The number of research or public papers from which data could be used was minimal. This limited number does not allow any further conclusions to be drawn from the data. Any analysis if done is usually a simple frequency analysis with no confidence scores. Because many courses have been run without being reported or updated, the exact or approximate numbers are difficult to ascertain.

Discussion

Principal Findings

This study aimed to review current trauma care training and describe the pattern of such training programs in Vietnam. We found that trauma care content was provided in both undergraduate and postgraduate training, as well as short-course training. However, the duration of such training was relatively short (under 5% of the curriculum has content related to trauma or first aid training). This result is similar to the report of inadequate training in trauma medicine of undergraduate students in the United Kingdom [40] or junior doctors in Australia [41]. Short-course training provided to medical staff who work in related fields might compensate for the deficiencies in undergraduate training.

Long-term Solutions

As previously mentioned, due to rapid growth in the economy and therefore access to private transport, the number of road trauma cases has increased substantially. However, the ability of the Vietnamese health care system to adapt to this situation is questionable. Although, according to the World Health Organization, between 1997 and 2017, the numbers of medical education universities and graduated doctors have nearly doubled and trebled, respectively [42], an internal report of the MOH questioned the quality of the training and standards of these doctors. The problem is that there has not been a unique national examination for all medical universities that leads to a minimum standard among qualified doctors. To resolve this deficiency, the Vietnamese MOH has proposed some solutions. In 2017, the Vietnamese government issued a decree (75/2017/ND-CP) to facilitate the establishment of a "national medical exam" to validate and standardize the health care workforce [43]. Additionally, the Vietnamese government has issued a decree (109/2016/ND-CP) promulgating practice certificates to health care practitioners [44]. To obtain this certificate, health care workers must practice in a specialty for at least 18 months. After that, there is a requirement for them to attend at least 48 hours of training (CME); otherwise, their certification is canceled. The other initiative is a project named "Health Professionals Education and Training for Health System Reform (HPET)," which is being organized by the MOH and was launched in 2014. The objective of this project was to improve the quality of education and training of health personnel, health management, and capacity building of primary health care [45]. These efforts are considered a long-term method of changing trauma training and medical education.

Taking China as an example, the pattern of trauma and injuries has witnessed a similar increase but on a larger scale due to the huge population, while there are limited specialist trainings. The Chinese government has applied some solutions. First, the duration of trauma training for orthopedic residents has been increased from 6 to 16 months. Second, extra courses, such as "Arbeitsgemeinschaft fur osteosynthesfragen" (Association for the Study of Internal Fixation) (AO) Basic, AO Advanced, and AO Masters, have been offered and welcomed by orthopedic surgeons. Finally, some superior trainees have been sponsored by the Chinese Association of Orthopedics (CAOs) to attend fellowship training abroad [46]. Likewise, the Indian government endeavored to tackle new challenges in trauma care. Besides the raising of road safety awareness in the population, the short-course basic trauma life support (BLS) has been widely taught for both professionals and amateur bystanders. Additionally, the National Board of Examinations has recently begun registering courses in trauma care and the Academy of Traumatology (India) under the "National Trauma Management Course" (NTMC). These courses have accreditation from the International Association of Trauma Surgery and Intensive Care (IATSIC) and have attempted to standardized education in trauma life support skills [46,47].

All methods listed above are promising initiatives that hope to address the deeply rooted problem of fragmented and unvalidated trauma teaching. However, these strategies will take time to be implemented and show dividends. Thus, other more immediate actions are required in the interim. Moreover, because undergraduate programs have not favored specialty training, students are ineligible for clinical treatments including trauma management. Because of this circumstance, further education needs to be carried out as an interim endeavor.

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Short-term Educational Interventions

Since 2008, the MOH of Vietnam has come up with a solution that is Project 1816. This project has contributed to enhancing the qualifications of lower-level hospitals, including first aid and primary trauma care. This project deploys health professionals of highly specialized hospitals to support the hospitals of lower levels for at least 3-month secondments [11]. The support includes training and education on trauma knowledge and practice for both doctors and nurses. By doing this, health care workers at the grassroot level can learn from their actual issues at work and apply their obtained skills directly to their routine work [48].

Organizing more basic short courses, which contain a trauma component (such as “basic surgery” and “basic anesthesia”), is also an effective solution. The proportion of trauma care lessons in these specific courses is over 30% (Table 1), significantly higher than those in undergraduate or other postgraduate training programs. Moreover, the courses are especially suitable for medical staff working at the grassroots level, where they function as the “frontline station” for trauma victims, as the courses require only 6 to 11 months to complete.

Table 1. Basic short-course program.

Variable	Course[a]	
	Surgery	Anesthesia
Training duration (months)	6	11
Credits (theory/practice), n	33.5 (10.5/23)	37 (12/25)
Credits related to trauma, n (%)	10.5 (31.2)	12 (32.0)

[a]Qualified general doctors are eligible, and assessment is performed with an essay and a clinical base.

Another possible solution is to organize short courses in the CME format, in which the content focuses on trauma care, such as BLS and primary trauma care (PTC). These courses are designed for basic first aid applied in all health care centers with limited resources [49-51]. Peter et al showed improvements in both the knowledge (58%-77%) and confidence (68%-90%) scores of 1050 candidates after finishing a trauma management training program [49]. Another study conducted by Sadiq and Alwawi also reported that the mean knowledge score of participants had improved after primary trauma care courses (from 16/30 to 21/30 and 47.2% to 78.8%) [50,51]. However, these reports also have significant limitations. They failed to show any effect on patient outcome, which is considered as the final target of all medical education interventions. In Vietnam, the evidence of these courses is even weaker. Some reports showed that PTC had been well received by local participants without any further assessment [52-54]. For these reasons, research to evaluate the outcome of trauma training short courses, such as BLS and PTC, should be conducted in LMICs like Vietnam.

Limitations

There are few papers on this topic, and they were mainly descriptive and lacked statistical methods. Because of this, we only conducted a narrative scoping review instead of a systematic review and meta-analysis. Hence, this article includes all the limitations of a scoping narrative method, including not formally assessing the quality of evidence and gathering information from a wide range of study designs and methods. In addition, we concentrated on the programs and curricula of HMU rather than all 27 medical schools in Vietnam. However, the differences among them were minimal, as they were all built according to a common MOH framework [55]. Moreover, due to limited resources, we could not include other types of medical education training, such as that for nursing and medical technicians.

Conclusions

Medical training in Vietnam has not adapted to the emerging new condition of road trauma. To address this, the implementation of short courses, such as BLS and PTC, can be considered to compensate for the insufficient competency-related trauma care among health care workers while waiting for medical training reform.

Acknowledgments

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Authors' Contributions

BTN contributed to conceptualization, data collection, data analysis, interpretation, and drafting the manuscript. TLP contributed to data collection, interpretation, drafting the manuscript, and critical revision of the article. THHK contributed to data collection, interpretation, drafting the manuscript, and critical revision of the article. VATN contributed to data collection, interpretation, drafting the manuscript, and critical revision of the article. CLB contributed to interpretation, critical revision of the article, and final edits. AP contributed to interpretation, critical revision of the article, and final edits. HTN contributed to data collection,

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interpretation, critical revision of the article, and final edits. TCQ contributed to data collection, interpretation, critical revision of the article, and final edits. MN contributed to conceptualization, supervision, interpretation, critical revision of the article, and final edits.

Conflicts of Interest

None declared.

Multimedia Appendix 1
Details of the search strategy.
[DOCX File , 17 KB - mededu_v8i1e34369_app1.docx]

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Abbreviations

BLS: basic trauma life support
CME: continuing medical education
HMU: Hanoi Medical University
LMIC: low- and middle-income country
MCQ: multiple-choice question
MOH: Ministry of Health
PTC: primary trauma care
RTI: road trauma injury
SL-I: specialized level I
SL-II: specialized level II

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Original Paper

Virtual Reality in Medical Students' Education: Scoping Review

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Abstract

Background: Virtual reality (VR) produces a virtual manifestation of the real world and has been shown to be useful as a digital education modality. As VR encompasses different modalities, tools, and applications, there is a need to explore how VR has been used in medical education.

Objective: The objective of this scoping review is to map existing research on the use of VR in undergraduate medical education and to identify areas of future research.

Methods: We performed a search of 4 bibliographic databases in December 2020. Data were extracted using a standardized data extraction form. The study was conducted according to the Joanna Briggs Institute methodology for scoping reviews and reported in line with the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines.

Results: Of the 114 included studies, 69 (60.5%) reported the use of commercially available surgical VR simulators. Other VR modalities included 3D models (15/114, 13.2%) and virtual worlds (20/114, 17.5%), which were mainly used for anatomy education. Most of the VR modalities included were semi-immersive (68/114, 59.6%) and were of high interactivity (79/114, 69.3%). There is limited evidence on the use of more novel VR modalities, such as mobile VR and virtual dissection tables (8/114, 7%), as well as the use of VR for nonsurgical and nonpsychomotor skills training (20/114, 17.5%) or in a group setting (16/114, 14%). Only 2.6% (3/114) of the studies reported the use of conceptual frameworks or theories in the design of VR.

Conclusions: Despite the extensive research available on VR in medical education, there continue to be important gaps in the evidence. Future studies should explore the use of VR for the development of nonpsychomotor skills and in areas other than surgery and anatomy.

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KEYWORDS

virtual reality; medical education; medical students; virtual worlds; digital health education

Introduction

Background

Traditionally, medical education comprises both theoretical learning in classrooms and clinical training in hospitals where students are able to gain clinical experience [1]. This is mainly done by means of face-to-face teaching. However, there has been a recent shift to the greater adoption of technology in medical education. This has been accelerated by the COVID-19 pandemic. After it was learned that transmission of COVID-19 is decreased by social distancing, educators were forced to rethink how best to teach students while decreasing face-to-face teaching [2]. To solve this problem, digital education has been proposed as a possible solution to improve medical education. Digital education (also known as electronic education or e-learning) is defined as the act of teaching and learning by means of digital technologies [3]. It is a broad term that

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encompasses a large number of different modalities, from a simple e-book to complex modalities such as virtual reality (VR), mobile learning, virtual patients (VPs), serious gaming and gamification, and digital skills trainers [4]. Although there is a wide range of digital education tools available, in this scoping review we will be focusing on investigating a single modality—VR.

VR is defined as an educational tool that uses computer technology to create a 3D image or environment that one can interact with in a seemingly real or physical way [5]. VR is a broad concept that has many different tools and applications. VR simulators can be classified into surgical VR simulators, 3D anatomical models, virtual dissection tables, virtual worlds or environments, and mobile VR. Surgical VR simulators consist of an interface connected to mechanical devices or haptic units and can be displayed on any screen but most commonly using a desktop [6]. Surgical VR simulators are most effective at developing users' technical psychomotor skills, such as for endoscopic surgery, because they can be used repeatedly and require very little time to set up [7]. 3D anatomical models allow users to explore 3D models by manipulating and rotating the model [8]. They are most commonly developed from 2D radiological images using different types of software tools [8]. Virtual dissection tables often overlap with 3D anatomical structures but are distinct in that they allow manipulation to *cut* digital models to reveal cross-sectional images; examples include the Anatomage Table [9]. Virtual worlds are 3D virtual environments based on multiplayer web-based gaming, freeing users from the constraints of location and time. Virtual worlds representing a clinical setting have been used to train emergency personnel on the management of situations involving mass casualties or major incidents [10-12]. Avatars representing patients can be generated to provide a more realistic simulation for the user [13]. Mobile VR refers to VR modalities designed for use on a touch screen mobile phone or tablet; examples include the Touch Surgery app [14].

VR can have diverse application in medical education. It has so far been most commonly used for the development of technical competencies, such as surgical skills, or for developing the ability to visualize anatomy in 3D. Examples of its applications include surgical technique training, the development of 3D visualization skills, and training for procedures such as cardiopulmonary resuscitation (CPR) [15-18]. However, VR can also be used to teach *soft skills* such as empathy and communication skills [13,19,20]. This commonly involves the use of avatars in a virtual world mimicking patients that respond in a certain way so that users can communicate with them [19]. Considering the large range of skills that can be taught with VR, coupled with the widespread reach and convenience of digital education, it holds great potential in the future of medical education.

Given the wide array of tools available in the VR toolbox and the diverse areas in which VR can be applied, there is a need to systematically identify the current VR applications used in medical education, as well as to identify any gaps in the current research of VR in medical education as reported in the literature. Although there are reviews aiming to map different applications of VR used in other types of health care education such as nursing and dentistry education, there seem to be none focusing on medical students' education [21,22]. Existing systematic reviews on VR in medical education mainly focus on assessing the effectiveness of VR within surgical disciplines, more specifically laparoscopic surgery and neurosurgery [23,24]. This scoping review aims to have a much broader focus by mapping out the extent of VR applications, rather than focusing on the effectiveness of VR in a specific subject.

Objective

The objective of this scoping review is to identify the different VR tools and applications in undergraduate or preregistration medical education as reported in the literature. We also aim to identify any gaps in the existing literature and provide suggestions for future research on the use of VR in medical education.

Methods

Overview

The scoping review was conducted in accordance with the Joanna Briggs Institute methodology for scoping reviews [25], which comprises the following six stages: (1) identifying the research question; (2) identifying relevant studies; (3) study selection; (4) charting the data; (5) collating, summarizing, and reporting the results; and (6) stakeholder consultation. The results were reported in line with the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) [26]. The protocol was registered on the Open Science Framework [27].

Stage 1: Identifying the Research Question

The objective of this scoping review is to outline the different VR modes available and the applications of VR in undergraduate or preregistration medical education. In line with the objectives of this scoping review, we have developed the following research questions:

1. How is VR used in undergraduate or preregistration medical education?
2. What are the main features of the VR applications in undergraduate or preregistration medical education?
3. What VR tools are available for undergraduate or preregistration medical education?
4. To which aspects of undergraduate or preregistration medical education has VR been applied?

Stage 2: Identifying Relevant Studies

A comprehensive search of the literature was performed using the following electronic databases: MEDLINE (Ovid), Embase (Elsevier), Cochrane Central Register of Controlled Trials (Wiley), and Education Resources Information Centre (Ovid). As a first step, a limited search using keywords was conducted in MEDLINE. The search strategy was piloted to check the appropriateness of the keywords and databases. In all retrieved papers, an analysis of the words contained within the title and abstracts as well as index terms was performed to develop a full search strategy. Thereafter, a second search using all the identified keywords and index terms was performed across all databases in December 2020. Finally, the third step included

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screening of the reference lists of all studies selected for this scoping review to look for additional sources. The complete search strategies for all databases can be found in Multimedia Appendix 1. The initial MEDLINE search strategy was developed with the help of a medical librarian experienced in the field. The search period ranged from 2010 to the present. We chose to start from 2010 because most literature pertaining to VR for education was published in recent years, as shown by our previous work in this area [28]. The capabilities of digital technology and VR have also changed substantially over time. We searched for literature in the English language only. All references identified were imported into the reference manager software, EndNote X9 (Clarivate). The references from different electronic databases were combined and any duplicate records removed.

Stage 3: Study Selection

The study selection followed a two-step screening process, which consisted of a title and abstract screening, followed by a full-text review. In both steps, 2 independent reviewers (JHW and SV) screened the articles against the eligibility criteria. Any disagreements were discussed, and if no consensus could be reached, a third reviewer (BMK) was consulted. We considered eligible studies based on the criteria presented in Textbox 1.

The first step involved the screening of the title and abstract of the studies using EndNote X9. To qualify for the full-text scan, the title and abstract had to (1) focus on the use of VR for educational use only and (2) have medical students as the target population. VPs, that is, computer-generated programs that simulate real-life clinical scenarios, can also be delivered in a VR format. In this scoping review, we included VR-based VPs. We also included studies on VR-based serious gaming education. Augmented reality (VR superimposed onto the real-world environment) [22] and mixed reality (mixing of both virtual and digital elements, allowing one to interact with both simultaneously) [29] are distinct entities that make use of VR and are not classified as VR. Studies focusing solely on mixed reality or augmented reality were excluded from this review.

We considered all primary studies, including experimental, observational, and qualitative study designs. Systematic reviews and meta-analyses were also considered. The full texts of the included studies were retrieved and their citation details imported. Studies excluded at this stage are described in Figure 1. This process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [30], and 2 review authors (JHW and SV) verified the final list of included studies.

Textbox 1. Full inclusion and exclusion criteria.

Inclusion criteria

- Studies on undergraduate or preregistration medical students in any geographical setting
- Studies involving the use of virtual reality together with another modality such as immersive virtual reality, virtual reality–based serious gaming, and virtual reality–based virtual patients
- All primary studies, regardless of study design, and relevant systematic reviews

Exclusion criteria

- Studies focusing only on virtual patient simulation, augmented reality, mixed reality, or serious gaming, without any involvement of virtual reality
- Studies published before 2010
- Studies in languages other than English
- Opinion pieces, viewpoints and conceptual frameworks, and conference abstracts

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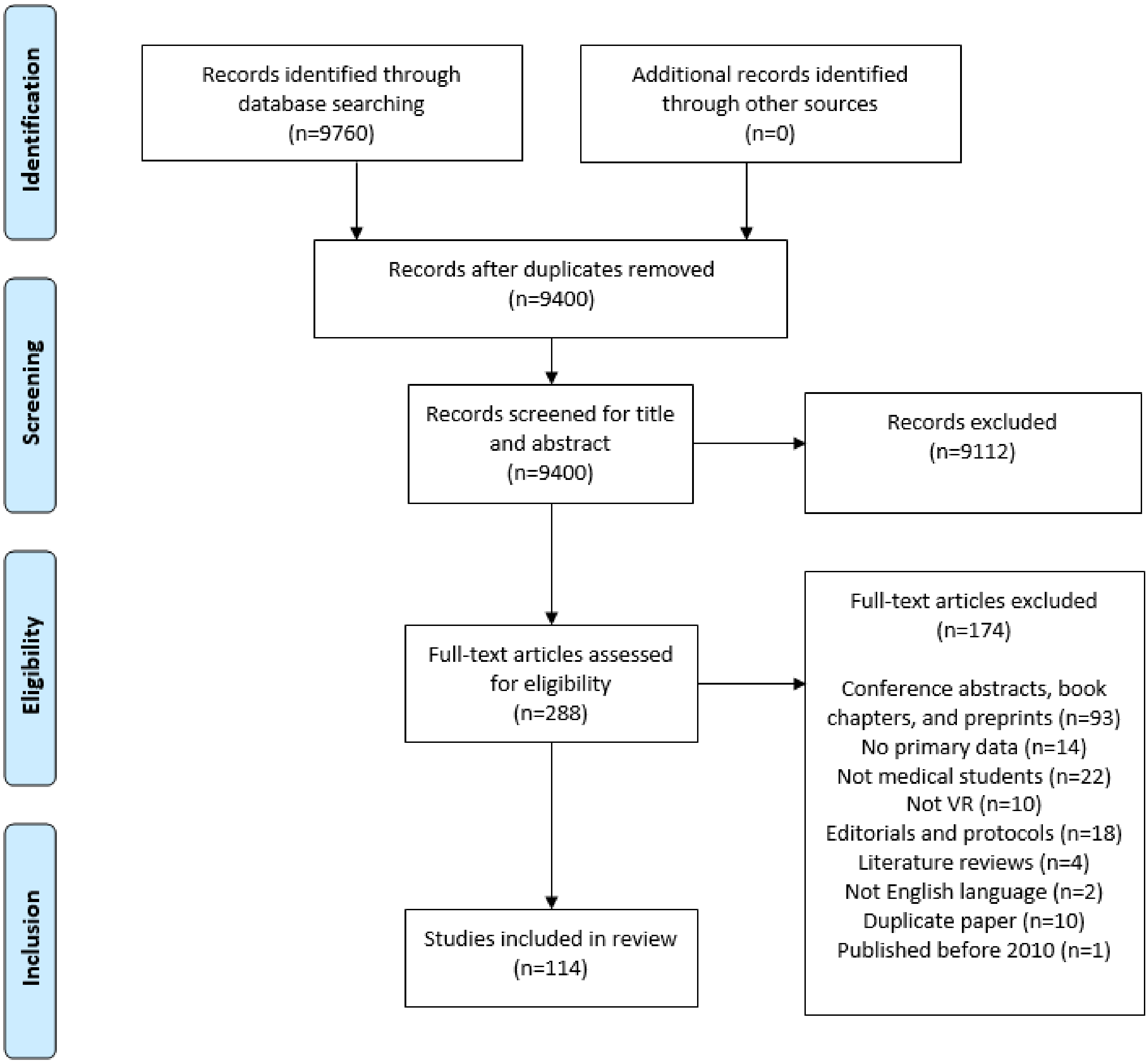
Figure 1. Flow diagram of the literature search and study selection process. VR: virtual reality.



Stage 4: Charting the Data

Relevant data were extracted from all included studies by 2 independent reviewers (JHW and SV). A structured data recording form developed by the reviewers was used and the information recorded using Microsoft Excel 2013. The full data extraction form can be found in Multimedia Appendix 2. The data extraction tool was piloted and revised as necessary during the process of extracting data from each study. Any disagreements that arose between the reviewers were resolved through discussion, and a third review author (BMK) acted as an arbiter when disagreements could not be resolved. We contacted the study authors for any missing or incomplete data.

Stage 5: Collating, Summarizing, and Reporting the Results

To characterize and summarize the results, a map of the data extracted from the included papers was presented in a diagrammatic or tabular form. In alignment with the objectives of this study, we provided an overview of the target participants, content of VR programs, types of studies included, and the context of each included study. The tabulated and charted results were accompanied by a narrative summary, which described how the results met the objectives and aims of this scoping review. We reported the findings in line with the PRISMA-ScR checklist [26]. Using the gap identification process, we detected areas where there was a paucity of data on VR content and its application in undergraduate or preregistration medical education.

We classified VR modalities based on the extent of immersion or interactivity. Immersion can be defined as the sensation of being disconnected with reality [31] or the amount of *presence* experienced by the user due to the illusion rendered by the VR modality [32]. The level of immersion is largely dependent on the number of senses the user uses to interact with the VR environment: the more the senses used, the more immersive the VR environment is said to be. This reflects the system's technical capabilities: the greater the number of sensorimotor contingencies the system has, the more immersive it will seem [33]. VR has generally been classified into two levels of

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immersion: immersive VR and nonimmersive VR. Fully immersive VR is defined as VR combined with devices that allow the user to visualize the recorded image in 3D in their entire field of vision and detect eye motions and leap motions of the hands. Nonimmersive VR involves computer-generated experiences on a desktop with which the user interacts by using a mouse [34]. For this study, we will define a third entity, *semi-immersive VR*, which does not fall into either of the 2 categories (eg, head-mounted devices that capture eye motions but do not capture hand motions and desktop-based VR, which provides tactile feedback).

Interactivity in VR refers to the extent to which the user can influence the content or form of the VR environment [32]. This can be classified into low, moderate, or high levels of interactivity. A low level of interactivity simply allows the user to choose information, such as using a mouse to select options that display different anatomical models. A moderate level of interactivity allows the user to add or delete objects in the VR environment, such as a virtual dissection tool that allows users to add or delete various anatomical structures individually. A high level of interactivity refers to when the VR environment responds appropriately to the user's input, such as using a joystick to manipulate the VR environment in a surgical simulator.

Step 6: Stakeholder Consultation

A stakeholder consultation was undertaken on August 12, 2021, with the aim of discussing and improving the presentation of our findings. No ethics approval was required as per Nanyang Technological University ethics board guidance. The stakeholder consultation consisted of a 1-hour-long web-based seminar. The audience comprised 18 researchers in the fields of medical education, digital health professions education, and health service research, as well as educators. The stakeholders were invited to share any comments, questions, or suggestions in relation to our study. In addition, we also specifically asked them to share their views on the most important aspects of our findings for researchers and educators, recommendations for future research, and suggestions on any other research in the field of VR or medical education that we should take note of. We have analyzed and presented our findings in this manuscript in line with the information collated through this stakeholder consultation.

Results

Included Studies

Our searches identified a total of 9400 studies after duplicates were removed, of which 288 (3.06%) were selected for full-text review. Of these 288 studies meeting the criteria for full-text review, 174 (60.4%) did not meet the inclusion criteria, resulting in 114 (39.6%) studies being included in this scoping review (Figure 1).

Study Characteristics

Of the included studies, most studies were either randomized controlled trials (RCTs; 47/114, 41.2%) or other experimental design studies (eg, before-and-after and cross-over studies; 49/114, 42.9%). Of the 114 studies, 14 (12.3%) were cross-sectional studies [35-49], 3 (2.6%) were case series or case studies [42,50,51], and 1 (0.9%) was a meta-analysis that examined the effectiveness of 3D anatomical models in teaching anatomy [52], which found that 3D anatomical models yielded significantly better results for user satisfaction and perceived effectiveness compared with conventional 2D teaching methods. An overview of the study characteristics is provided in Table 1.

Among the 96 RCTs and experimental studies included, 50 (52%) compared VR against a traditional learning method (eg, box trainer and video-based lectures), 27 (28%) evaluated VR modalities by changing another variable (eg, VR vs VR with warm-up and VR with guidance vs no guidance) [9,14,48,49,53-94], 14 (15%) did not have any intervention (eg, before-and-after studies and learning curves) [95-109], and 5 (5%) compared a VR modality against another type of VR modality (eg, LapSim vs ProMIS) [110-113].

Of the 114 studies, 30 (26.3%) were from the United States, 11 (9.6%) each from the United Kingdom and Germany, 9 (7.9%) each from Canada and Denmark, and 13 (11.4%) from Asia. Other countries were uncommon, with notably no studies being published from Africa or any low-income country.

Ethics approval was mentioned in 61.4% (70/114) of the studies, and the source of funding was mentioned in 40.4% (46/114) of the studies. Among the 46 studies that received funding, 19 (41%) received funding from the university, 12 (26%) received charitable funding, 9 (20%) received government-backed funding, and 6 (13%) received private funding.

There was generally an increase in frequency of publication from 2010 to 2020, with 7.9% (9/114) of the studies published in 2010 and 17.5% (20/114) of the studies published in 2020 (Figure 2).

On the basis of our review of the literature on VR in medical students' education, we categorized the findings from the included studies as follows: (1) students, (2) VR modalities, (3) development, (4) input and output devices, (5) extent of immersion and interactivity, (6) subjects taught, (7) teaching strategies, and (8) assessment methods. These categories will be explored next.

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Table 1. Characteristics of included studies (N=114).

Domain and feature	Values, n (%)
Study design	
Randomized controlled trial	47 (41.2)
Experimental (eg, cross-over and before-and-after studies)	49 (42.9)
Cross-sectional studies	14 (12.3)
Cases studies and case series	3 (2.6)
Meta-analysis	1 (1.1)
Location (by country)	
United States	30 (26.3)
Germany	11 (9.6)
United Kingdom	11 (9.6)
Canada	9 (7.9)
Denmark	9 (7.9)
Others	44 (38.6)
Number of students	
0-50	76 (66.7)
51-100	20 (17.5)
>100	18 (15.8)
Year of study of students[a]	
1	31 (27.2)
2	29 (25.4)
3	26 (22.8)
4	23 (20.2)
5	19 (16.7)
6	19 (16.7)
Study setting	
University	108 (94.7)
Hospital	6 (5.3)
VR[b] **modalities used**	
Surgical VR simulator	69 (60.5)
3D anatomical model	14 (12.2)
Virtual dissection table	4 (3.5)
Virtual worlds	21 (18.4)
Mobile VR	4 (3.5)
Others	2 (1.8)
Mode of access	
Commercial product	84 (73.6)
Developed in-house	30 (26.3)
Both commercial and in-house elements	5 (4.4)
Input devices	
Haptic tools	71 (62.2)
Mouse	21 (18.4)

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Domain and feature	Values, n (%)
Touch screen	8 (7.4)
Game controllers	5 (4.4)
Joysticks	2 (1.8)
VR gloves	2 (1.8)
Headset	4 (3.5)
Stereoscopic glasses	1 (0.9)
Delivery devices	
Screen	100 (87.7)
Headset	13 (11.4)
3D projector with stereoscopic glasses	1 (0.9)
Extent of immersion	
Fully immersive	20 (17.5)
Semi-immersive	68 (59.6)
Nonimmersive	26 (22.8)
Extent of interactivity	
High	79 (69.3)
Moderate	19 (16.7)
Low	16 (14)
Subject taught[a]	
Surgical psychomotor skills	71 (61.4)
Anatomy	21 (18.4)
Clinical management[c]	16 (14)
Radiology	4 (3.5)
Nonsurgical psychomotor skills	3 (2.6)
Communication	3 (2.6)
Mode of teaching	
Self-directed	71 (62.3)
Guided	42 (36.8)
Not available[d]	1 (0.9)
Duration of teaching	
<1 day	35 (30.7)
1 day to 1 month	28 (24.6)
1-6 months	16 (14)
6-12 months	8 (7)
>1 year	4 (3.5)
Not specified	23 (20.1)
Timing of assessment	
Immediate	96 (84.2)
Delayed	17 (14.9)
Not available[d]	1 (0.9)
Individual or group delivery[a]	
Individual	97 (85.1)

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Domain and feature	Values, n (%)
Individual and group	7 (6.1)
Group	9 (7.9)
Not available[d]	1 (0.9)

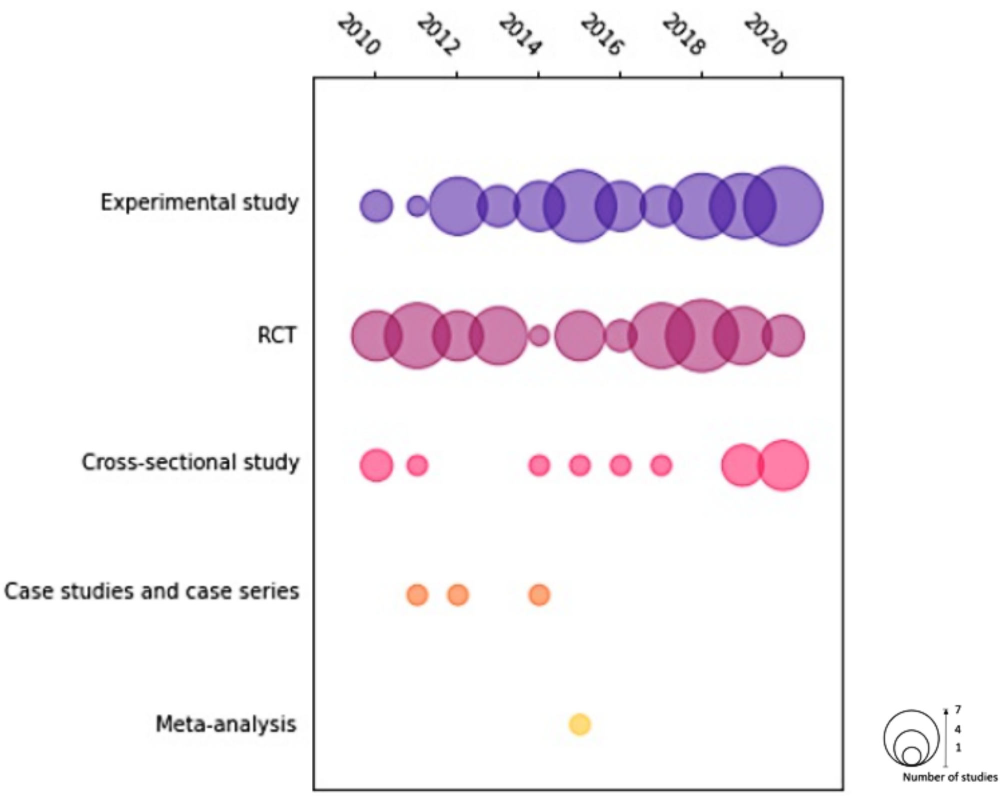
[a]Percentages do not add up to 100% because of overlap among the included studies.

[b]VR: virtual reality.

[c]Examples include cardiopulmonary resuscitation, pediatric respiratory management, clinical presentation, and trauma management.

[d]The systematic review did not investigate any mode of teaching.

Figure 2. Publication frequency by year of the articles included in this study. RCT: randomized controlled trial.



Students

Of the 114 studies, 76 (66.7%) involved ≤50 students, 20 (17.5%) involved 51-100 students, and 18 (15.8%) involved >100 students. All years of study of medical students were generally well represented, with a slight tendency to include lower-year medical students.

Most of the studies (108/114, 95.7%) took place in a university setting, with the remainder (6/114, 5.3%) taking place in a hospital setting [111,114-118].

VR Modalities

Of the 114 papers, 69 (60.5%) concerned surgical VR simulators [36,37,42,46,47,51,53,55-57,59,66,67,73-75,79,81-84,86,88,90-94,96, 98-100,103,105,107-138], 20 (17.5%) used virtual worlds or virtual environments [39-41,43, 44,48,50,58,69,70,76-78,101, 139-145], 15 (13.2%) used 3D anatomical models, 4 (3.5%) used virtual dissection tables [9,62,97,127,146], 4 (3.5%) used mobile VR [14,63,65,147], 1 (0.9%) examined the use of a virtual palpation simulator, and 1 (0.9%) used a virtual ultrasound simulator (Figure 3).

Most surgical VR simulators were evaluated using either RCTs (34/69, 49%) or experimental studies (29/69, 42%). Similarly, most 3D anatomical models were also evaluated by either RCTs (6/15, 40%) or experimental studies (6/15, 40%). Virtual worlds were mainly evaluated using experimental studies (8/20, 40%) or cross-sectional studies (8/20, 40%). Mobile VR was mainly evaluated through RCTs (3/4, 75%), whereas virtual dissection tables were mainly evaluated through experimental studies (3/4, 75%; Figure 4).

Among the studies using surgical simulators, approximately one-third (22/69, 32%) [42,53,59,74,82,86,89,91, 94,105,110,111,113, 119,122,123,128,130, 132,136,148] used some version of LAP Mentor [149]. There were also a notable number of studies using ARTHRO Mentor [150] (7/69, 10%) [36,56,66,110,112,120,121], Eyesi Virtual Simulator (3/69, 4%) [37, 51,133], da Vinci Surgical Simulator (4/69, 6%) [90,96,117,118], dV-Trainer (4/69, 6%) [82,88,103,126],

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VBLaST suturing simulator (3/69, 4%) [49,84,99], and SimSurgery (3/69, 4%) [106,125,131]. Other surgical VR simulators were uncommon.

Among the studies using 3D anatomical models, most (11/15, 73%) were developed in-house by the authors themselves, with the exception of some studies in which commercial products were used. They include Surgical Theater's Precision VR visualization platform, which is a commercial product used to visualize cerebrovascular anatomy using a controller [35], and DIVA, which is a 3D VR platform used for craniofacial trauma education [151].

Among the 20 studies involving virtual worlds, 15 (75%) were developed in-house, whereas the remaining 5 (25%) used virtual worlds that are commercial products, including products such as MicroSim [58], Body Interact [141], Otago virtual hospital [50], a beta version of CPR VR learning software [70], and Medical Realities VR [87].

Among the 4 studies involving the use of virtual dissection tables, 2 (50%) used the Anatomage Table [9,146], 1 (25%) used the Sectra Virtual Dissection Table [97], and 1 (25%) used the VH Dissector Pro [62].

Among the 4 studies involving the use of mobile VR, 3 (75%) used the Touch Surgery app, a mobile surgical training platform [14,65,152], and 1 (25%) used the aVOR app, a teaching, training, and testing tool for the vestibulo-ocular reflex system and its disorders [63].

The most common commercial products described in the literature are summarized in Textbox 2.

Figure 3. Number of papers of each VR modality published by year. VR: virtual reality.

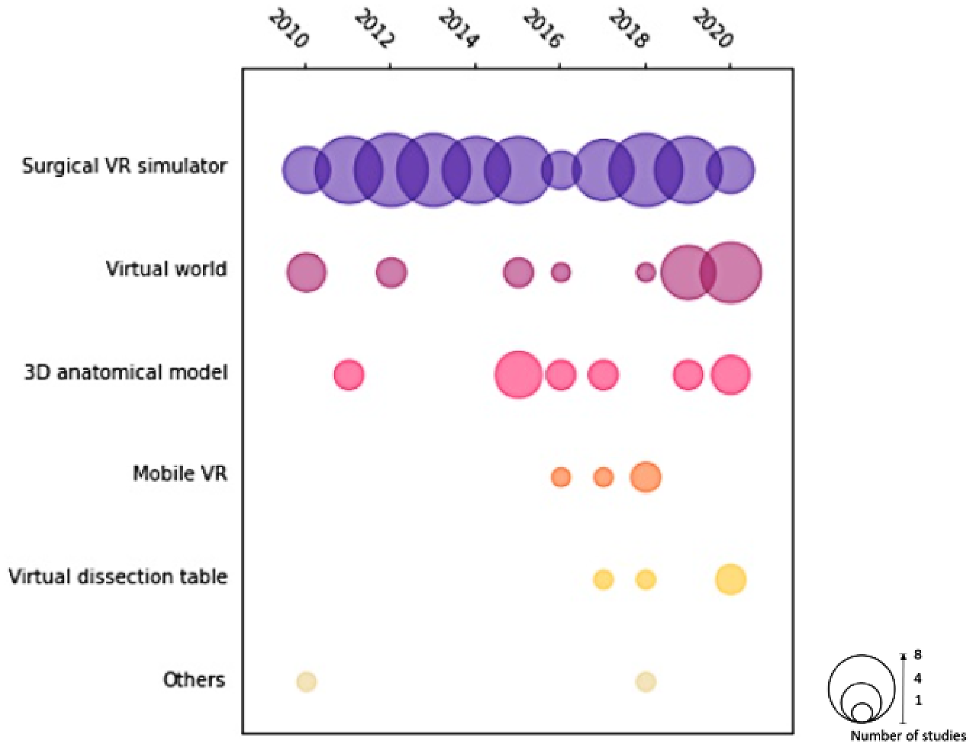

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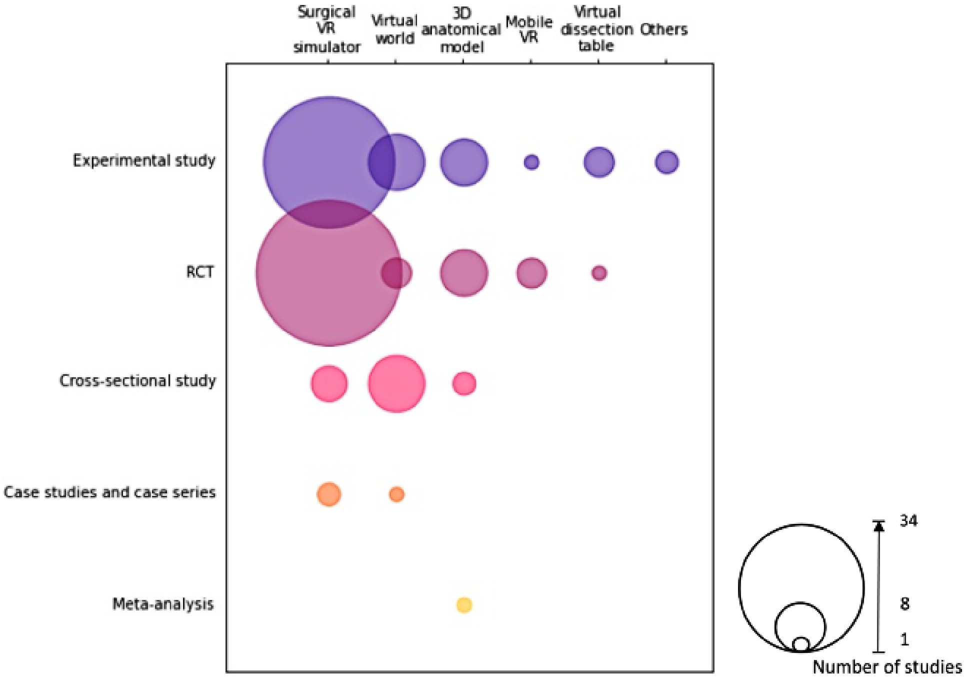
Figure 4. VR modality described against study design. RCT: randomized controlled trial; VR: virtual reality.



Textbox 2. Common commercial virtual reality (VR) products used in the included studies.

VR modalities and types of tools used

- Surgical VR simulators
  - LAP Mentor
  - ARTHRO Mentor
  - Eyesi Virtual Simulator
  - da Vinci Surgical Simulator
  - dV-Trainer
  - VBLaST suturing simulator
- Virtual worlds
  - MicroSim
  - Body Interact
  - Otago virtual hospital
- Virtual dissection tables
  - Anatomage Table
  - Sectra Virtual Dissection Table
  - VH Dissector Pro
- Mobile VR
  - Touch Surgery app
  - aVOR app

Development

Of the 114 studies, 35 (30.7%) used a VR modality that was developed in-house. The information used in development can be broadly classified into four different categories: development of 3D anatomical models, virtual worlds, VPs (clinical scenarios), and probes and haptic devices.

Of the VR modalities developed in-house, 37% (13/35) were 3D anatomical models. Of these 13 studies, 12 (92%) developed

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3D anatomical models that used some form of transverse 2D images in their development, either through magnetic resonance imaging or computed tomography images or transverse cross-sectional images of human cadavers. The information was imported into a software program that could convert the 2D images into 3D models (eg, Mimics, Macromedia Flash, and After Effects) [153]. Any defects or irregularities would then be smoothened out manually by means of the software. The model would then be imported into VR platforms (eg, Unreal Engine VR platform and HTC Vive software development kit) where it could be displayed on various VR modalities. The remaining study used 2D diagrams and anatomical descriptions from textbooks and journals [85].

Of the VR modalities developed in-house, 43% (15/35) were virtual worlds. Virtual worlds followed a somewhat similar development pathway but differed in terms of the software and information used and the outcomes of development. Whereas 3D anatomical models aim to produce a model that can be manipulated by the user on a screen, the structures in 3D worlds do not require as great a degree of manipulation; they mainly involve the users exploring the models and interacting with other users through an avatar, and this influences the software used in development. Structures in virtual worlds were mainly built from standard building shapes such as blocks, spheres, and tubes and are called *primitives* or *prisms* [40]. Of the 15 studies focusing on virtual worlds, 5 (33%) used the Second Life platform to develop the virtual world structure, whereas 3 (20%) used Amira. Once the virtual world was completed, users would download the program on a desktop and have to learn the interface before accessing the resources in the world.

Of the 15 studies that examined virtual worlds, 4 (27%) used VPs [41,43,50,101]. The VPs used in the simulations were designed with a predefined set of responses to questions asked by the user. These responses are usually written onto a script and programmed into the VP. In addition, the modality in the study by Guetterman et al [101] used intelligent VPs that can detect body motion as well as facial expression and speech and then modify their responses appropriately and thus can also train the user in nonverbal behaviors. Another modality incorporated a dynamic analysis process where the program was able to compare the user's performance with that of peers and expert choices and provide feedback in real time [41]. The study by Kleinert et al [43] also noted the importance of incorporating established game design elements to promote long-time motivation, such as a reward system.

Of the 35 studies that used a VR modality that was developed in-house, 7 (20%) examined the development of probes and haptic devices. Of these 7 studies, 5 (71%) [48,57,112,145,154]. used a surgical VR simulator that was developed in-house and described the processes involved in fine-tuning the VR simulator for students' use. The probes and haptic devices used in these studies were mainly commercially acquired, but the fine-tuning of these devices was performed in-house. This was mainly done by examining the learning curves of the VR simulators and determining the accuracy and reproducibility of the probes and haptic devices involved. This allowed researchers to determine the optimal sensitivity of the probes and the optimal duration of training. Of the 7 studies, the remaining 2 (29%) described the development of novel VR simulators with unique haptic devices. The study by Karadogan et al [104], which described the use of a virtual palpation simulator, was mainly focused on designing a haptic device needed to quantify the amount of force needed to be applied to the haptic device to instill a change in the VR environment. This was measured using the Weber fraction, which is defined as the ratio of the minimum difference that a person can distinguish to the standard intensity of the stimulus in a sensory modality. The second study involved designing a virtual ophthalmoscope that used a cylindrical plastic canister to view photos of the fundus using the ophthalmoscope [46]. The study also focused on adopting *gamification* to improve students' use of the simulator.

In all the studies with VR modalities developed in-house, the main persons in charge of development of the VR modality were the authors themselves. In addition, 60% (21/35) of the studies mentioned the inclusion of additional experts such as ear, nose, and throat (ENT) surgeons; radiologists; or other specialists in the area of interest to help with validation of the study [37,43,44,46,50,58,63-66,71,72,77,78,85,88,120,121,133,147,155].

There were generally very few frameworks or theories applied in the development of VR simulators in medical education. Among the 35 studies that used a VR modality developed in-house, only 3 (9%) involved any frameworks or theories when developing the VR modality. The study by Lorenzo-Alvarez et al [78], which investigated the design of game-based learning in virtual worlds, used theories on human learning, especially behaviorism, cognitivism, and constructivism. The study by Makransky et al [44], which investigated the feasibility of developing a desktop VR laboratory simulation on the topic of genetics, used feedback based on the cognitive theory of multimedia learning. The study by Hayward et al [41], which designed a novel tool for teaching diagnostic reasoning, used script theory, which states that the clinician draws upon prestored reasoning pathways in the form of illness scripts or *profiles* when navigating new patient encounters.

Input and Output Devices

Of the 114 studies, 71 (62.2%) used a haptic surgical tool as their input interface [36,37,42,47,49,51,55,56,59,66,67,73-75,79,81-84,88-91,94,96,99,100,102-113,115-126,128,129,131-138,148,156] (Figure 4). The next most common input device was a mouse (21/114, 18.4%) [8,38-41,43-45,50,54,58,61,62,64,68,71,76-78,80,92,101,139-142,144,151,157-164], followed by touch screen (8/114, 7%) [9,14,63,65,97,127,146,147,165,166] and handheld game controllers (5/114, 4.4%) [35,57,87,153,155]. Of the 114 studies, 4 (3.5%) [46,143,144,167] used headset devices such as Oculus Rift VR System, Google Cardboard version 1, and RITECH II, whereas 2 (1.8%) used joysticks [69,168] and 3 (2.6%) [70,95,169] used VR gloves. The study by Kockro et al [72] used stereoscopic glasses as the input device (Figure S1 in Multimedia Appendix 3).

The delivery devices used include the use of screens in most of the studies (100/114, 87.7%) [8,9,14,35-47,49-51,53-56,58,59,61-69,71,73-79,81,83-86,88-91,93-95,97-104,106-117,119-129,131-138,140-144,146,147,151,156-159,

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161-166,168,170,171], headset (13/114, 11.4%) [48,57,70,80,82,87,92,95,96,105,118,145,153,155,167,172], and 3D projector with stereoscopic glasses (1/114, 0.9%) [72] (Figure S2 in Multimedia Appendix 3).

Extent of Immersion and Interactivity

Most of the studies included modalities that were of high interactivity (79/114, 69.3%) [35-37,42,43,45-51,55-57,59,66,67,70,73-75,79,81-84,86-91,93,94,96,98-100,102,103,105-113,115,116,118-129,131-135,137,143,145-147,156,168,171,173,174], whereas 16.7% (19/114) of the studies [9,38-41,62-64,68,69,76-78,97,104,140,141,151,153,159,161,162,165,169] included modalities that were of moderate interactivity and 14% (16/114) of the studies included modalities that were of low interactivity [8,14,44,54,58,61,65,71,72,80,85,87,92,101,142,155,157,158,160,163,164, 167,172,175] (Figure S3 in Multimedia Appendix 3).

In terms of immersion, most of the studies included modalities that were semi-immersive (68/114, 59.6%) [36,37,42-44,47,49,51,53,55,56,59,61,66,67,69,73,75,81,83,84,86,88,89,91,93,94,96,99-101,103,106,108,109,111-117,120,121,123-129,131-139,142,146,156,166,168-170,176], followed by nonimmersive (26/114, 22.8%) [8,9,14,38,39,41,45,50,54,58,62,63,65,68,71,72,76-78,85,97,101,140,141,147,157-159,161,162,164,165,171] and fully immersive (20/114, 17.5%) [35,46,48,57,70,74,80,82,87,90,92,110,118,119,145,151,153,155,167,172] (Figure S4 in Multimedia Appendix 3).

Of the 114 studies, 14 (12.3%) were both of high interactivity and fully immersive [35,46,48,57,70,74,82,90,105,110,118,119,145,154]. Of these 14 studies, 9 (64%) involved the development of surgical psychomotor skills: 6 (67%) for laparoscopy [74,82,105,110,118,119] and 1 (11%) each for neurosurgery [35], orthopedics [57], and robotic surgery [90]. Of the 14 studies, 4 (29%) were relating to clinical management: 3 (75%) for pediatrics [48,145,154] and 1 (25%) for CPR [70]. The study by Wilson et al [46] was relating to ophthalmology anatomy. Keeping to definitions of immersion and interactivity, the VR modalities used in these studies allowed the user to visualize the environment, had motion-tracking capability, and allowed the user to manipulate the VR environment in real time.

Subjects Taught

From the studies, six broad subjects taught were identified: surgical psychomotor skills, anatomy, clinical management of various conditions, radiology, communication, and nonsurgical psychomotor skills.

The most common subject taught was surgical psychomotor skills, with 62.3% (71/114) of the studies including it as a subject taught [14,35-37,47,49,51,53,55-57,59,65-67,73-75,79,81-84,86-91,93,94,96,99,100,103,105-126,128-138,147,148]. The second most common subject taught was anatomy, with 18.4% (21/114) of the studies including it as a subject taught [9,35,38,40,46,52,54,61,62,64,68,71,72,80,85,92,97,146,153,155,166], followed by 14% (16/114) of the studies including clinical management of various conditions as one of the subjects taught [39,41,43-45,48,50,58,63,69,70,140,141,145,154,167], 3.5% (4/114) of the studies including radiology as a subject taught [64,76-78], 2.6% (3/114) of the studies including nonsurgical psychomotor skills as a subject taught [42,102,104], and 2.6% (3/114) of the studies including communication as one of the subjects taught [44,50,101] (Figure S5 in Multimedia Appendix 3).

Of the 114 studies, 4 (3.5%) taught a combination of subjects. Of these 4 studies, 2 (50%) combined the teaching of clinical management and communication [44,50], 1 (25%) combined anatomy with radiology [64], and 1 (25%) combined anatomy with the development of surgical psychomotor skills [35].

With a focus on surgical psychomotor skills, most of these VR modalities involved the handling of laparoscopic surgeries (39/71, 55%). Of these 39 studies, 23 (59%) explored basic laparoscopic handling skills [49,59,67,74,79,81,83,84,86,96,99,105,108,111,113, 117,118,123,128,130, 131,148] and 16 (41%) explored advanced laparoscopic surgery procedures [75,82,87,89,91,94,106,110,119,122,125,129, 132,134,136,137] such as cholecystectomy, appendectomy, salpingectomy, and Nissen fundoplication.

Of the 71 studies with a focus on surgical psychomotor skills, 7 (10%) involved arthroscopic VR modalities. Of these 7 studies, 3 (43%) provided training in basic arthroscopic skills [112,120,121], 2 (29%) pertained to knee arthroscopy [56,107], 1 (14%) pertained to hip arthroscopy [36], and 1 (14%) pertained to shoulder arthroscopy [66].

Among the remaining 35% (25/71) of the studies that examined surgical psychomotor skills, specific procedures were involved, such as ENT [114-116,124,138], endoscopy [73,93,100,135], ophthalmology [37,51,55,133], robotic surgery [90,103,126], neurosurgery [35,47], orthopedics [57,147], vascular surgery [53,109], microsurgery [14], urology [88], and emergency procedures (chest tube placement) [65].

Among the studies that explored anatomy, the most prevalent topic was neuroanatomy (6/21, 29%) [35,54,62,64,72,155], followed by regional anatomy (5/21, 24%) [9,52,92,97,146], ENT (3/21, 14%) [68,85,166], vascular anatomy (2/21, 10%) [38,61], and specific anatomical structures (5/21, 24%) [40,46,71,80,153].

Of the 16 studies that included clinical management, 4 (25%) included CPR as a management procedure [39,58,70,140], 3 (19%) were on pediatric respiratory management [48,145,154], and 2 (13%) were on general clinical presentation management [41,141], whereas the remaining 7 (44%) were on specific clinical and situational management procedures, including neurological management for benign paroxysmal positional vertigo [63], trauma [69], surgical [43], palliative [167], prenatal genetic screening [44], patient interaction [50], and clinical ethics management [45].

Of the 4 radiology studies, 3 (75%) pertained to general radiology [76-78] and 1 (25%) explored neuroanatomy together with neuroradiology [64].

Of the 114 studies, 3 (2.6%) involved VR training for nonsurgical psychomotor skills, including intravenous cannulation [42], ultrasound manipulation [102], and palpation

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[104]. Finally, of the 114 studies, 3 (2.6%) pertained to communication training, which included empathy [101], professionalism in clinical context [50], and prenatal genetic screening [44].

Teaching Strategies

Most of the studies (103/114, 90.4%) were conducted outside of the medical students' curriculum, whereas 9.6% (10/114) of the studies assessed VR modalities that were incorporated into the curriculum. Among these 10 studies, the most common method of incorporating VR modalities into the curriculum was either by incorporating 3D anatomical models or virtual dissection tables into anatomy education (4/10, 40%) [38,72,97,146] or by incorporating virtual-world scenarios into clinical placements (4/10, 40%) [45,46,48,145], such as training students how to react to different situations that may be difficult to replicate in real life. The remaining 20% (2/20) of the studies incorporated the VR modality in the final year of study to better prepare students before they graduate. The study by De Ponti et al [141] prepared students for the clinical management of cardiovascular, cerebrovascular, trauma, pulmonary, infective, gynecological, gastrointestinal, renal, and metabolic endocrinology clinical cases, and the study by Paschold et al [106] prepared students for handling laparoscopic instruments in retraction of tissue and cystic duct and artery clipping.

More than half of the studies involved students engaging in self-directed learning with the VR modalities they were provided (71/114, 62%) [14,36,37,40,42-47,49,51,53,56,57,65-68,71-76,78-82,84,85,87-89,91-93,99-105,107,109-112,114-116,118-121,123,125,126,128,129,131,132,146,148,153,155,166,167]. Of the remaining 43 studies, 42 (98%) [9,35,38,39,41,48,50,54,55,58,59,61-64,69,70,77,83,86,90,94,96,97,106,108,113,117,122,124,130,133-138,140,141,145,147,154] described students engaging in guided teaching sessions with VR use, whereas 1 (2%) did not provide clear description of student guidance [52].

Of the 42 studies with guided VR training sessions, 26 (62%) asked external experts to guide the students in the topic explored through VR [35,38,48,58,59,61-63,86,90,94,97,106,108,117,122,124,130,133-136,141,145,147,154]. With regard to the external experts, their number and specialty varied greatly. Examples of external experts guiding students in various subjects included experienced surgeons' demonstration and commentary on laparoscopic surgery [59], an anatomy instructor teaching an anatomy lesson [61], and otorhinolaryngology residents teaching clinical management of benign paroxysmal positional vertigo [63].

Between the self-directed and guided VR trainings, most of the studies incorporated an introductory session where time was allocated for students to become familiar with the VR system they were provided. Among the 71 self-directed studies, 58 (82%) used an introductory session [36,37,42-44,46,47,49,51,53,56,57,65,68,73-76,78,82,84,85,87-89,91-93,99,100,102,103,105,107,109-112,114-116,118,120,121,123,125,126,128,129,131,132,146,153,155,166]. This took on many forms, such as watching demonstration videos [111,112,121], printed instructions [75,112], or live demonstration [65,100]. A few of the studies (9/71, 13%) did not introduce self-directed students to the use of the VR modality [45,66,67,71,72,81,101,104,167]. However, most of the VR modalities used in these studies had guides built into the VR programs.

Of the 71 studies with guided teaching, 36 (51%) incorporated an introduction for the VR modality [35,39,41,48,55,58,59,61-64,69,77,83,86,90,94,96,106,108,113,117,122,124,130,133-138,140,141,145,147,154], whereas 6 (8%) [9,38,50,54,70,97] did not explicitly state that time was set aside for an introduction to the VR modality. Interestingly, of these 6 studies, 5 (83%) were conducted as part of the medical curriculum. Of these 5 studies, 1 (20%) [9] was conducted over a week. Although the authors did not explicitly set aside time for orientation to the VR modality, there may have been more time available in total for students to get familiar with the VR equipment.

Duration of Teaching

There was a wide variation in VR use periods in the studies. Hence, they were categorized into the following time periods: <1 day, 1 day to 1 month, 1-6 months, 6-12 months, and >1 year. For studies with duration >1 month, the 6-month threshold was chosen to distinguish between an academic semester and an academic year.

The most common lengths of teaching periods were <1 day (35/114, 30.7%) [38,43-45,50,53,54,64,71-73,75-77,79,80,83,88,89,91,92,106,107,109,116,118,122,129,134,137,147,153,155,166,167] and 1 day to 1 month (28/114, 24.6%) [9,37,42,48,49,57-59, 69,74,78,84-86,90, 99,100,104,108,110,123-126,130,131,145,154].

Fewer studies opted for longer teaching periods. Of the 114 studies, 16 (14%) used teaching periods lasting 1-6 months [36,39,56,63,65,66,81,87,97,105,111,135,136,146,148], 8 (7%) used periods lasting 6-12 months [35,40,67,94,114,120,121,141], and 4 (3.5%) were conducted over periods lasting >1 year [41,70,115,140].

Of the 114 studies, 4 (3.5%) investigated attainment of proficiency over time, and thus a predetermined training duration was not applicable [82,113,128,133], whereas 1 (0.9%) was a meta-analysis, and thus training duration was not applicable either [52]. The teaching period was not specified in 15.8% (18/114) of the studies [14,46,47,51,55,61,62,68,93,96,101-103,112,117, 119,132,138].

Delivery of VR Modalities to Individuals or Groups

The studies had variations in the number of students who were taught using 1 VR device. Hence, the studies were categorized into those that used VR modalities that facilitated teaching an individual and those that facilitated group teaching (>1 person). Some VR modalities were more flexible: they allowed for teaching either an individual or a group.

Most of the study designs involved individual students taught using VR modalities (97/114, 85.1%) [14,36,37,42-49,51,53-59,63,65-67,69-71,73-76,78-82,84-94,96,99-126,128-138,141,145-148,153-155,166,167]. A few studies used VR teaching modalities for both individual and group teaching (7/114, 6.1%)

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[35,40,41,61,62,64,68], whereas some used it solely for group teaching (9/114, 7.9%) [9,38,39,50,72,77,83,97,140]. VR delivery was not applicable for 0.9% (1/114) of the studies [52].

There were distinct group sizes that were characteristic of the modality of VR used. Some studies used small teaching groups of approximately 2-4 students [140]. These VR modalities used virtual world scenario-based teaching methods and involved working in small teams for learning. Other studies used classroom-size teaching methods with 20-30 students [38,72]. These studies mainly focused on anatomy teaching with the use of stereoscopic 3D projectors. Finally, some studies incorporated VR modalities that allowed for trainings to be conducted to hundreds of students at once [77]. These VR modalities were characteristically virtual world massively multiplayer online games such as Second Life.

Discussion

Summary of Findings

In this scoping review, we mapped out the existing VR modalities used in undergraduate medical education, including the characteristics of the VR modalities, target population, tools used in development, educational elements, and the outcomes measured of each VR modality. We found 114 studies that were relevant to our objective, including 47 (41.2%) RCTs, 49 (42.9%) other experimental study designs, 14 (12.3%) cross-over studies, 3 (2.6%) case studies and cases series, and 1 (0.9%) meta-analysis. Most of the papers were published from Europe or the United States. Approximately half of the papers reported the use of surgical VR simulators, with the next most common being 3D anatomical models and virtual worlds. Other VR modalities such as virtual dissection tables and mobile VR were less common. The included studies usually used haptic tools or a mouse as input devices and a screen as a delivery device. Most of the studies were semi-immersive with a high degree of interactivity. The most common subject taught using VR simulators was surgical skills, and the most common mode of training was self-directed. There was a large variation in the duration of teaching. Most studies reported only a single type of outcome measurement, with the most common being skills outcomes. The timing of assessment was most often immediately after the intervention. Most VR modalities were also designed for individual delivery rather than group delivery.

Comparison With Existing Literature and Future Recommendations

Although surgical VR simulators, 3D anatomical models, and virtual worlds are relatively well represented in the literature, there is limited evidence on the use of virtual dissection tables and mobile VR. Indeed, there are a number of systematic reviews evaluating the use of surgical VR simulators in health professions education at both postgraduate and undergraduate level, most of which favor VR, especially for nonsimulation training [177-179]. The relative lack of studies on virtual dissection tables and mobile VR could be due to the fact that these VR modalities are more novel and have been reported in the literature only from 2015 onward, as revealed by our search strategy. Furthermore, some popular VR anatomy applications are not assessed in the included studies, such as Complete Anatomy (3D4Medical) [150] and Anatomy.tv (Primal Pictures) [180]. It seems that although a wide variety of VR tools were mentioned in the results, there are other VR tools that may be commonly used but not mentioned in the literature. Future studies should examine the effectiveness of the use of novel VR modalities in different settings, for example, remote, home-based learning, such as in the case of mobile VR modalities.

Most of the studies included in our review did not report, or refer to, educational or behavior frameworks or theories used in the development of VR applications. This has also been observed in studies on other digital modalities used in health professions education [3]. However, explicit use of frameworks or theories for the design of complex interventions such as the use of VR in education has an important role for improving the quality, transparency, and reproducibility of research. Future research should aim to incorporate and report on the adoption of such frameworks in the design of VR applications where possible.

We also observed several studies exploring the development of particular 3D anatomical models and virtual worlds that had a considerable overlap in terms of the process of development. There is a need for stronger collaboration and easier sharing among educators and researchers in this novel field. This could be achieved through a common platform or database of VR medical education tools and insights similar to Radiopaedia for radiology and GitHub for software engineering.

There is a clear lack of studies from low- and middle-income countries. Adoption of VR tools shown to be effective in high-income countries might not be possible in other settings because of context-specific limitations such as lack of financial resources, knowledge, or technology [181,182]. Given the potential that VR has in improving medical education, there is a need for development and evaluation of VR tools that would be specific to low- and middle-income countries.

We also observed a distinct lack of studies focusing on the use of VR for developing *soft skills* such as communication skills or empathy. The manner in which health care professionals communicate with patients is argued to be as important as clinical knowledge but often goes underemphasized [50,101]. VPs in particular can be programmed to respond in different manners depending on the response of the user and offer an exciting opportunity to develop students' communication skills from the comfort of their own homes. There is also scope for more research exploring the use of VR for nonsurgical skills development.

Immersive VR modalities not only offer a realistic experience to the user, but they also have the additional benefit of spatial understanding [155]. The higher the level of immersion, the greater the spatial understanding, which can result in greater effectiveness of scientific visualization. It also helps to reduce the information clutter wrought by the overlapping icons and controls of 2D environments [21]. However, highly immersive systems can be costly and resource intensive [28]. Most of the studies in this review were semi-immersive in nature, possibly to optimize realism while avoiding high costs. Future studies

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should explore the use of VR modalities with high immersion. Correspondingly, there is scope for more research on VR delivered through headsets and VR using input devices other than haptic surgical tools or a mouse.

Only a few studies reported on the integration of VR training presented in the study into medical school curricula [35,70,141]. Although VR is being increasingly implemented at medical schools worldwide, the literature reporting its implementation and adoption is scarce. This is coupled with a lack of guidance or information on how best to adopt different VR modalities in the curriculum. There is a need for clear guidance and recommendations with the aim of enabling optimal adoption and harnessing of VR within medical curricula.

Strengths and Limitations

We performed a comprehensive search of 4 major bibliographic databases in this review. We covered the search period starting from 2010 to include all available studies on VR-based training for medical students' education. Our screening and data extraction were also conducted in parallel and independently to ensure reliability and reduce bias in our findings. The topic that we explored was also novel, particularly in the context of undergraduate medical education.

This scoping review was limited to studies published in English. Because of the large number of studies on VR, we only focused our research on the use of VR in medical students' education and thus the use of VR in other health care professionals' education and training was not captured in this review. Diverse terminology was used to describe VR; therefore, we may not have captured some studies because of the unfamiliar terminology used. In the categorization of the diverse terminology used in the studies, details specific to singular studies may have been lost. Although this review is as comprehensive as possible, there may still be smaller but important studies that were published only as abstracts that were left out of this review. In accordance with scoping review methodology, there was no quality assessment of the included articles; thus, the included studies may be biased or incomplete in terms of some of the information reported.

Conclusions

The use of VR in medical education is a rapidly expanding and exciting field of study. Current research is mostly centered on surgical VR simulators, virtual worlds, and 3D anatomical models by comparing them with traditional modes of learning. Novel VR modalities such as mobile VR and virtual dissection tables, which are potentially more portable and allow for group learning, respectively, are less well represented in the literature. As an increasing number of medical schools turn toward incorporating VR into their curriculum, there is a need to evaluate these novel VR modalities as well as describe the methods used to incorporate VR into the curriculum. The use of VR to develop communication skills or to allow students to work in a team is also lacking. Most of the VR modalities described are only designed for a single user, which is unlike situations arising in a health care team. The use of modalities such as virtual worlds to create scenarios that require teamwork and communication should be more widely explored.

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Authors' Contributions

LTC conceived the idea for the review. JHW, SV, and JKW wrote the review. JHW, SV, JKW, and LKK helped in the data extraction and analysis process. LTC provided methodological guidance and critically revised the manuscript. SRM reviewed the work critically and provided feedback. All authors gave their approval for the final version of the work to be published and agreed to be accountable for the integrity of the work published.

Conflicts of Interest

None declared.

Multimedia Appendix 1
Search strategies.
[DOCX File , 14 KB - mededu_v8i1e34860_app1.docx]

Multimedia Appendix 2
Data extraction form.
[DOCX File , 14 KB - mededu_v8i1e34860_app2.docx]

Multimedia Appendix 3
Supplementary figures.
[DOCX File , 23 KB - mededu_v8i1e34860_app3.docx]

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Abbreviations

CPR: cardiopulmonary resuscitation
ENT: ear, nose, and throat
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PRISMA-ScR: Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews
RCT: randomized controlled trial
VP: virtual patient
VR: virtual reality

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Original Paper

Digital Teaching in Medical Education: Scientific Literature Landscape Review

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Abstract

Background: Digital teaching in medical education has grown in popularity in the recent years. However, to the best of our knowledge, no bibliometric report to date has been published that analyzes this important literature set to reveal prevailing topics and trends and their impacts reflected in citation counts.

Objective: We used a bibliometric approach to unveil and evaluate the scientific literature on digital teaching research in medical education, demonstrating recurring research topics, productive authors, research organizations, countries, and journals. We further aimed to discuss some of the topics and findings reported by specific highly cited works.

Methods: The Web of Science electronic database was searched to identify relevant papers on digital teaching research in medical education. Basic bibliographic data were obtained by the “Analyze” and “Create Citation Report” functions of the database. Complete bibliographic data were exported to VOSviewer for further analyses. Visualization maps were generated to display the recurring author keywords and terms mentioned in the titles and abstracts of the publications.

Results: The analysis was based on data from 3978 papers that were identified. The literature received worldwide contributions with the most productive countries being the United States and United Kingdom. Reviews were significantly more cited, but the citations between open access vs non–open access papers did not significantly differ. Some themes were cited more often, reflected by terms such as virtual reality, innovation, trial, effectiveness, and anatomy. Different aspects in medical education were experimented for digital teaching, such as gross anatomy education, histology, complementary medicine, medicinal chemistry, and basic life support. Some studies have shown that digital teaching could increase learning satisfaction, knowledge gain, and even cost-effectiveness. More studies were conducted on trainees than on undergraduate students.

Conclusions: Digital teaching in medical education is expected to flourish in the future, especially during this era of COVID-19 pandemic.

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KEYWORDS

medical education; digital teaching; virtual reality; augmented reality; anatomy; basic life support; satisfaction; bibliometric; medicine; life support; online learning; literature; trend; citation

Introduction

Rapid advancements in information technology and worldwide internet access potentially allow for the full substitution of traditional face-to-face medical education with digital teaching methods (including but not limited to remote teaching). Overall, digital teaching applications may be categorized as distance learning applications vs computer-assisted interaction [1]. In the early and mid-1980s, the very first online courses for undergraduate, postgraduate, and adult education were established, and even online degree programs were introduced [2]. With the public access to the World Wide Web granted by its developers in the early 1990s, digital teaching has become increasingly popular. Similar to traditional face-to-face teaching, digital teaching also needs to be approached from various perspectives, such as achieving competency in pedagogical, technological, and content knowledge [3]. To maintain a positive learning experience, the teaching environment should also account for social, cognitive, and teaching presence [4]. Digital teaching is considered challenging and often faces a rather high attrition rate in comparison to on-campus teaching due to various reasons, including technical difficulties, perceived isolation, content confusion, poor academic performance, and lack of motivation [5]. Digital teaching allows for more flexibility with work or family commitments [6,7] and reduces costs [8,9]. However, some studies have questioned the degree of improvement of student outcomes by remote learning [7,10,11]. In addition, although students experience digital learning as an entertaining new way to study, they do not consider it to replace classical didactic methods [12]. Often, digital teaching is used together with traditional approaches in so-called hybrid (blended) learning. Although it has received higher acceptance by students, blended learning did not exhibit a significant difference in comparison to the traditional methods based on final test scores [13,14]. Digital teaching in medical education shares similarities with other educational areas as it enhances self-directed learning and computer literacy skills. Yet it also follows its own specific aims, such as to enhance collaboration skills, problem solving skills, critical thinking, and filling the gap between theory and practice [15].

These teaching methods gained great importance during the COVID-19 pandemic, as remote teaching methods provided the opportunity to bypass the mitigation measurements (eg, social distancing). This is reflected by an enormous increase in online and remote schooling during the time of the pandemic [16,17]. In the context of medical education, digital teaching is applicable for teaching medical students, resident or specialty training, and continuing medical education of physicians. Available medical digital teaching platforms were primarily utilized by medical schools and consisted of video clips, virtual models, and so on. Positive aspects of these platforms are the possibility of regular updates, easy accessibility, and proven efficiency of knowledge transfer allowing self-directed learning [11]. Importantly, knowledge transfer is believed to be a key element of medical education, and success in this form of self-directed learning means being able to apply knowledge in a new context, which was being learned in another context beforehand [18]. The major potential barriers for digital teaching applications in medical education are several: the presence of technology or infrastructure (valid especially for low-income countries); institutional support; trained educators; and overall acceptance by the students.

Thousands of scientific studies have explored different kinds of digital teaching applications in medical education. In this work, we aimed to gain insights into the tendencies and features of this scientific area by the application of a total scale bibliometric analysis, an approach that has proven its value in the characterization of diverse scientific areas with medical significance [19-21]. We also aimed to identify the most productive entities and reveal recurring terms from the current literature on digital teaching in medical education.

Methods

Data Source and Search Strategy

On July 1, 2021, the digital Web of Science (WoS) core collection database was accessed and queried with the following search string: TOPIC: ("eTeaching*" OR "online teaching*" OR "E-teaching*" OR "electronic teaching*" OR "computer-assisted teaching*" OR "computer-mediated teaching*" OR "computer-based teaching*" OR "digital teaching*" OR "online course*" OR "eLearning*" OR "online learning*" OR "E-learning*" OR "electronic learning*" OR "computer-assisted learning*" OR "computer-mediated learning*" OR "computer-based learning*" OR "digital learning*") AND TOPIC: ("medic*"). The query identified publications mentioning these words and their derivatives in the title, abstract and, keywords. The "Analyze" and "Create Citation Report" functions of WoS were deployed for initial analyses and frequency counting. The full records of the resultant publications were exported to VOSviewer, version 1.6.15 (Leiden University) for further bibliometric analyses. Normalized citations were computed in VOSviewer by considering the average number of citations received by the documents published in the same year and included in the data set (a score of >1 indicates higher-than-average citations compared with the documents published in the same year). As an exploratory analysis, we further analyzed publications with authors based on low-income economies according to the World Bank [22].

Visualization of Scientific Landscapes

The VOSviewer [23] generated bubble maps that visualized the recurring terms and their citation per publication (CPP). Terms that appeared in at least 1% of the analyzed publications (n≥40) were visualized. Similarly, author keywords that appeared in at least 3 publications were visualized.

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Statistical Analysis

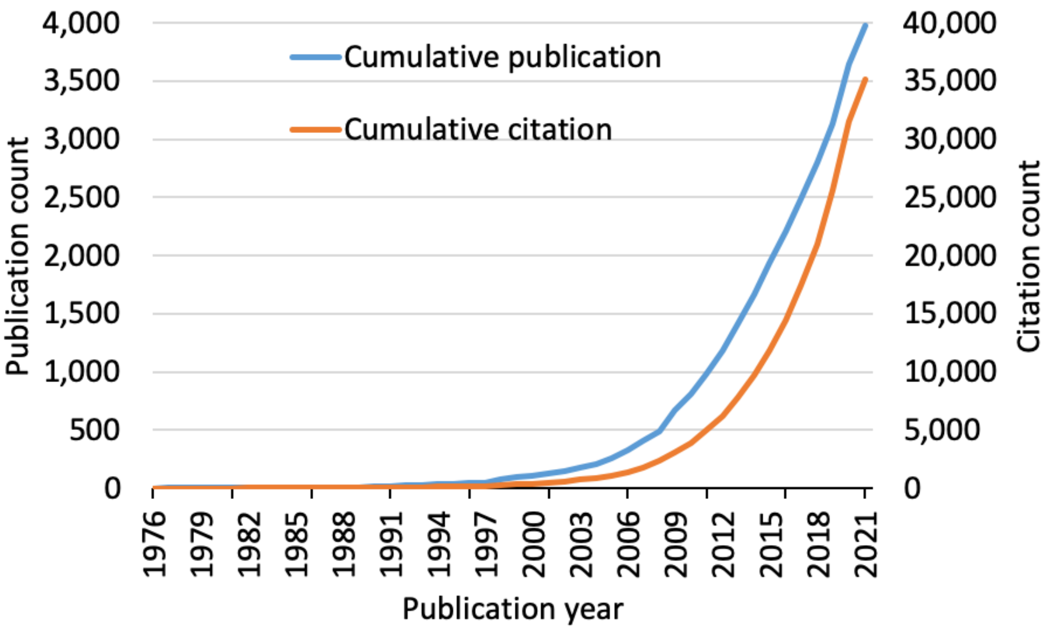
Two-sample *t* tests were conducted to analyze if the CPP showed a significant difference between original articles and reviews, and between open access (OA) and non-OA papers. Statistical tests were performed with SPSS, version 26.0 (IBM Corp). The results were deemed significant if *P*<.05.

Results

Overall Literature Landscape

Our literature search yielded a total of 3978 documents, which collectively accumulated 35,104 citations (Figure 1), reflecting a CPP of 8.82 and h-index of 65. The first paper on this topic was published in Lancet in 1976, reporting the experimentation of computer-assisted learning among 5th year medical students at Glasgow University [24]. The study reported that 79 out of 80 students were keen to have further such tuition. Meanwhile, in 2020, when the COVID-19 pandemic affected the whole world, the yearly publication count on digital teaching suddenly increased to 515, up from 200-300 in the prior 7 years. About 72.1% of the retrieved documents were original articles (n=2870, CPP=9.8), whereas 6.0% were reviews (n=239, CPP=21.0). The remaining were mainly proceedings papers, editorial materials, and meeting abstracts. Hence, the article-to-review ratio was 12:1. Less than half (41.5%) were OA (n=1649, CPP=9.3), whereas over half were non-OA (n=2329, CPP=8.5). Reviews were significantly more often cited (*P*<.001) than original articles. Moreover, the citations between OA vs non-OA papers did not significantly differ (*P*=.331).

Figure 1. Cumulative publication and citation count of digital teaching in medical education.



The most productive authors, organizations, journals, and journal categories are listed in Table 1. The contributors were mostly from Europe and North America. The reports were mainly published in medical education journals.

The recurring terms in the titles and abstracts of the papers are depicted in Figure 2. Some themes were more highly cited (yellow bubbles), including general terms such as innovation (n=129 [3.2%], CPP=16.4), trial (n=220 [5.5%], CPP=14.3), effectiveness (n=474 [11.9%], CPP=14.8); terms describing modalities of digital teaching such as virtual reality (n=47 [1.2%], CPP=16.9), simulation (n=241 [6.1%], CPP=12.6), and massive open online course (MOOC), n=57 [1.4%], CPP=11.8); terms characterizing teaching disciplines such as anatomy (n=163 [4.1%], CPP=16.2), nursing (n=122 [3.1%], CPP=13.3), and surgery (n=129 [3.2%], CPP=8.8). It seemed that more studies were conducted on trainee (n=198 [5%], CPP=8.5) than undergraduate student (n=62 [1.6%], CPP=10.1). The recurring author keywords are depicted in Figure 3A (note that, for clarity, the following dominating keywords were omitted from the figure: e-learning [n=1010], medical education [n=500], education [n=352], online learning [n=240], blended learning [n=162], and elearning [n=108]). Different aspects in medical education were implied in digital teaching, such as gross anatomy education (n=50 [1.3%], CPP=31.0), histology (n=14 [0.4%], CPP=17.7), complementary medicine (n=6 [0.2%], CPP=3.0), medicinal chemistry (n=17 [0.4%], CPP=5.1), and basic life support (n=4 [0.1%], CPP=6.0). The term “COVID-19” had a rather low CPP. If we computed average normalized citations by normalizing the citations by the mean number of citations received by the documents published in the same year and included them in the data set, the recency yet importance of COVID-19 could be illustrated (normalized citation=1.95, where the citation rate achieved is equal to 1) (Figure 3B). Top 10 recurring keywords are listed in Table 2.

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Table 1. Top 5 most productive authors, organizations, countries, journals, and journal categories.

Categories and subitems		CPP[a]
Author, n (%)		
Martin R Fischer	27 (0.7)	21.3
David A Cook	18 (0.5)	55.9
Kieran Walsh	18 (0.5)	7.4
John Sandars	14 (0.4)	19.5
Nabil Zary	13 (0.3)	6.5
Organization, n (%)		
University of London	91 (2.3)	13.6
University of Toronto	86 (2.2)	12.9
Harvard University	77 (1.9)	9.1
University of California System	69 (1.7)	10.8
University of Munich	61 (1.5)	14.1
Country, n (%)		
The United States	991 (24.9)	12.0
The United Kingdom	558 (14.0)	13.1
Germany	434 (10.9)	7.3
Canada	310 (7.8)	13.4
Australia	237 (6.0)	11.0
Journal, n (%)		
BMC Medical Education	158 (4.0)	12.4
Medical Teacher	118 (3.0)	22.7
EDULEARN Proceedings	76 (1.9)	0.5
Anatomical Sciences Education	73 (1.8)	26.6
Studies in Health Technology and Informatics	54 (1.4)	3.1
Journal category, n (%)		
Education, scientific disciplines	910 (22.9)	14.5
Education, educational research	757 (19.0)	5.7
Health care sciences services	554 (13.9)	17.6
General internal medicine	351 (8.8)	8.2
Medical informatics	210 (5.3)	10.6

[a]CPP: citation per publication.

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Figure 2. Term map showing recurring terms (n≥40) from the titles and abstracts of the analyzed papers. Bubble colors indicate citations per publication, their size indicates frequency count, and their proximity indicates the frequency of their coappearance.

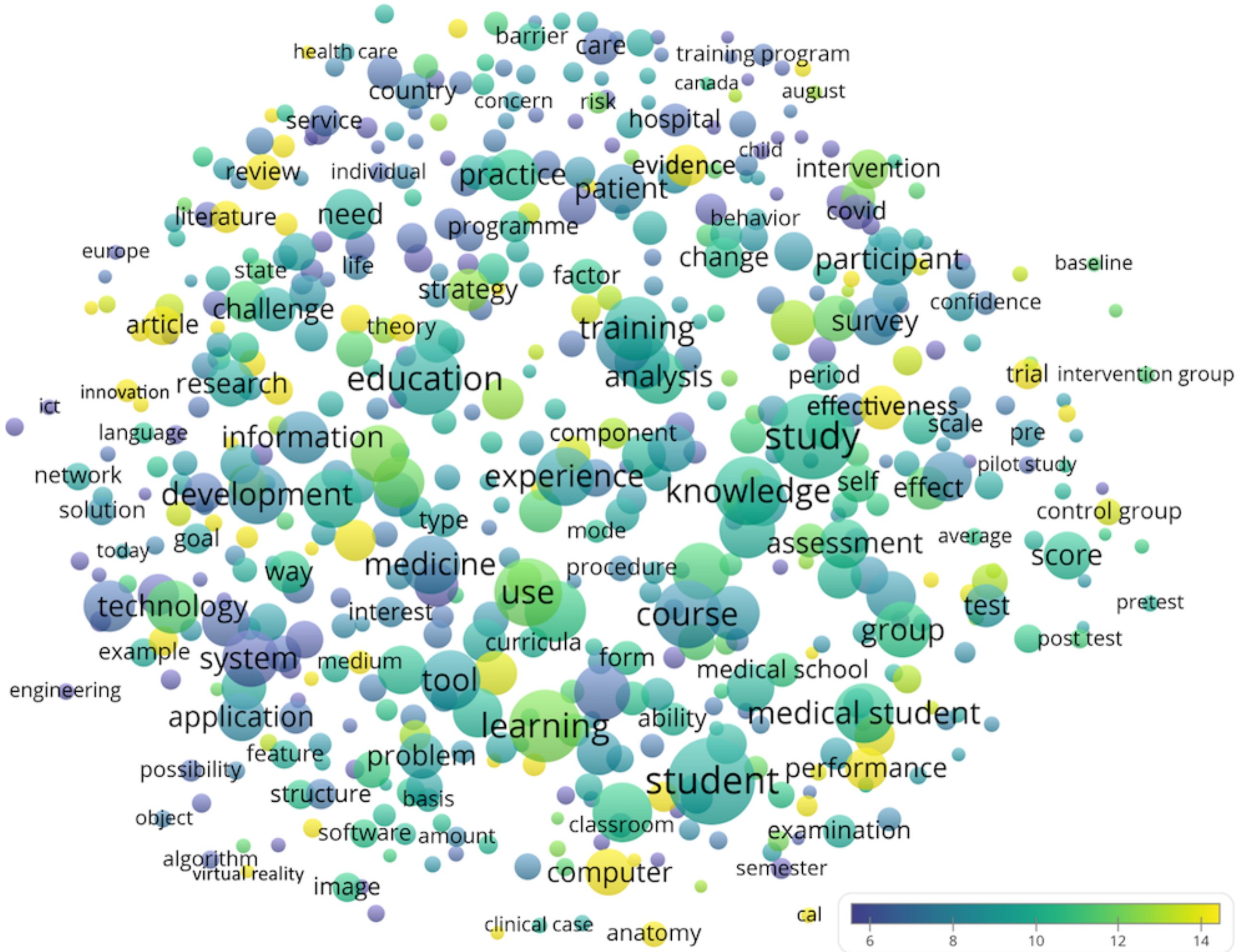

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Figure 3. Term map showing recurring author keywords (n≥3) from the analyzed papers. Bubble color indicates (a) citations per publication and (b) average normalized citations (score of >1 indicates higher-than-average citations). Bubble sizes indicate frequency count and their proximity indicates the frequency of their coappearances.

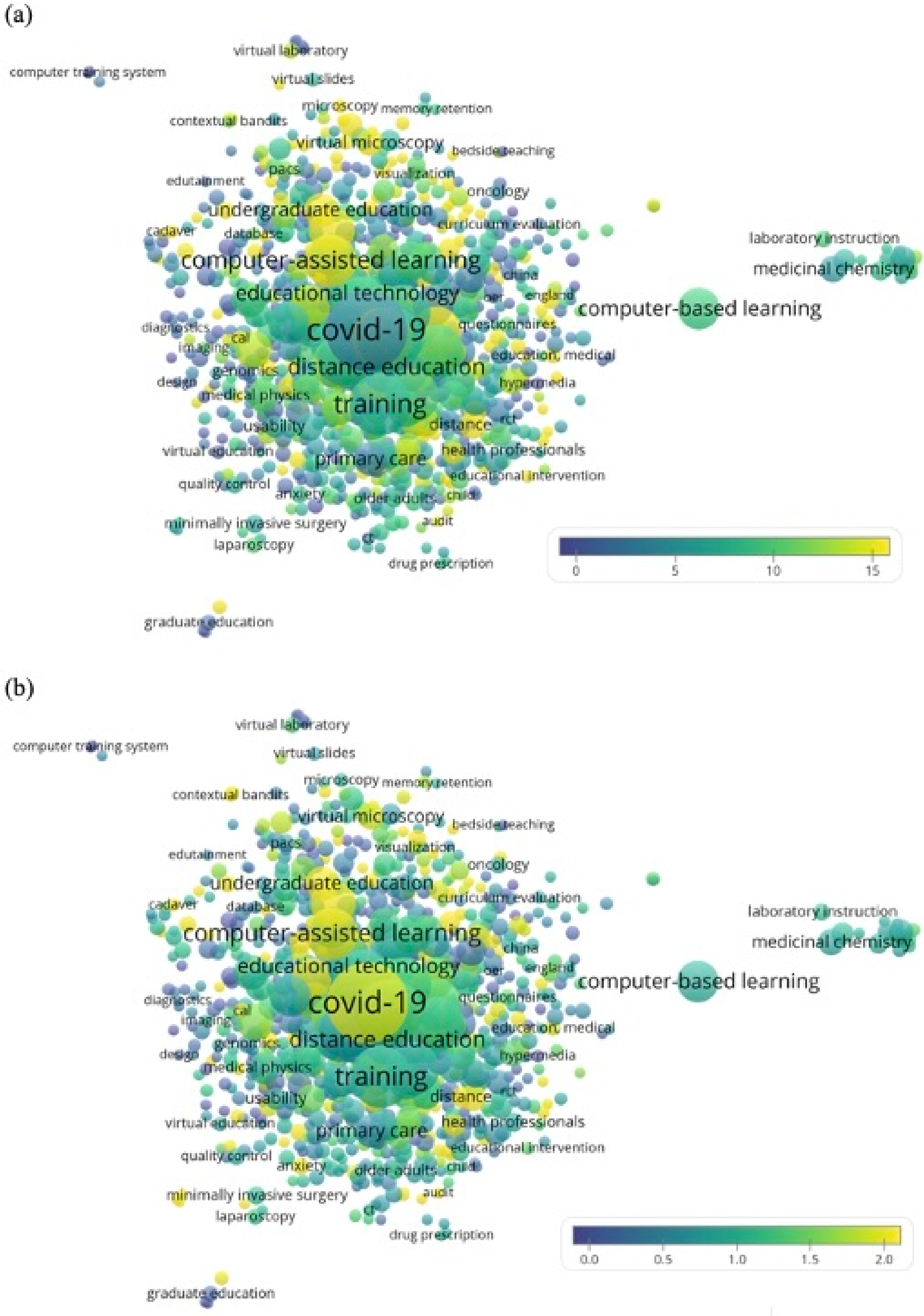

Table 2. Top 10 recurring author keywords from the entire data set and from the low-income country publications.

Entire data set	n (%)	CPP[a]	Low-income country publications	n (%)	CPP
COVID-19	156 (3.9)	3.0	E-learning	9 (0.2)	23.8
Medical students	100 (2.5)	7.5	Medical education	4 (0.1)	45.3
Training	91 (2.3)	7.1	Training	3 (0.1)	2.7
Internet	87 (2.2)	14.7	Challenges	2 (0.1)	5.0
Teaching	82 (2.1)	9.2	COVID-19	2 (0.1)	4.5
Learning	73 (1.8)	7.0	Malawi	2 (0.1)	3.5
Evaluation	70 (1.8)	7.3	Research capacity strengthening	2 (0.1)	5.0
Continuing medical education	68 (1.7)	9.8	Undergraduate	2 (0.1)	2
Simulation	68 (1.7)	9.1	Low- and middle-income countries	1 (0.1)	170
Computer-assisted learning	66 (1.7)	26.5	Resource constrained	1 (0.1)	170

[a]CPP: citation per publication.

For completeness, Table 3 lists the top 10 most cited papers based on total and yearly citation count, respectively. Ranking by yearly citation count showed that many of the top 10 papers concerned COVID-19.

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Table 3. Top 10 most cited papers based on total and yearly citation counts.

Paper	Reference	Total citations	Yearly citations
Top 10 by total citations			
Ruiz JG, Mintzer MJ, Leipzig RM. The impact of E-learning in medical education.	[11]	982	61.4
Ellaway R, Masters K. AMEE Guide 32: e-Learning in medical education Part 1: Learning, teaching and assessment.	[25]	298	21.3
Greenhalgh T. Computer assisted learning in undergraduate medical education.	[26]	220	10.5
Childs et al. Effective e‐learning for health professionals and students—barriers and their solutions. A systematic review of the literature—findings from the HeXL project.	[27]	205	12.1
Cook DA. Web-based learning: pros, cons and controversies.	[28]	201	13.4
Cook DA. The research we still are not doing: an agenda for the study of computer-based learning.	[29]	184	10.8
Hamilton R. Nurses' knowledge and skill retention following cardiopulmonary resuscitation training: a review of the literature.	[30]	174	10.2
Frehywot et al. E-learning in medical education in resource constrained low-and middle-income countries.	[31]	170	18.9
Liu Q et al. The effectiveness of blended learning in health professions: systematic review and meta-analysis.	[32]	161	26.8
Mehta et al. Just imagine: new paradigms for medical education.	[33]	158	17.6
Top 10 by yearly citations			
Ruiz JG, Mintzer MJ, Leipzig RM. The impact of E-learning in medical education.	[11]	982	61.4
Thai NTT, De Wever B, Valcke M. The impact of a flipped classroom design on learning performance in higher education: Looking for the best "blend" of lectures and guiding questions with feedback.	[34]	138	27.6
Liu et al. The effectiveness of blended learning in health professions: systematic review and meta-analysis.	[32]	161	26.8
O'Doherty et al. Barriers and solutions to online learning in medical education–an integrative review.	[35]	102	25.5
Aristovnik et al. Impacts of the COVID-19 pandemic on life of higher education students: A global perspective.	[36]	44	22.0
Ellaway R, Masters K. AMEE Guide 32: e-Learning in medical education Part 1: Learning, teaching and assessment.	[25]	298	21.3
Mukhtar et al. Advantages, Limitations and Recommendations for online learning during COVID-19 pandemic era. Pakistan journal of medical sciences.	[37]	41	20.5
Sandhu P, de Wolf M. The impact of COVID-19 on the undergraduate medical curriculum. Med Educ Online.	[38]	39	19.5
Schneider SL, Council ML. Distance learning in the era of COVID-19. Archives of dermatological research.	[39]	19	19.0
Frehywot et al. E-learning in medical education in resource constrained low-and middle-income countries.	[31]	170	18.9
Pei L, Wu H. Does online learning work better than offline learning in undergraduate medical education? A systematic review and meta-analysis.	[40]	54	18.0

By examining the data, we noticed that one of the keywords with highest CPP was "low- and middle-income countries" (n=3 [0.1%], CPP=57.7), listed by 2 original articles and 1 review [31,41,42]. Hence, we searched for this phrase in the entire data set (not limited to author keywords) and identified 19 original articles (CPP=6.9) and 7 reviews (CPP=44.1). These numbers suggested that the original research works on this aspect were not highly cited. For instance, the most cited work was a survey among students, residents, and lecturers in a medical faculty in Cameroon (38 citations) [43]. This work found that 84% of students and 58% of residents never had access to digital teaching resources but viewed digital teaching positively and wished to have it in their school. Thus, a high need for digital resources for medical teaching exists, at least in some parts of the world. To address such needs, the University of Dundee and the British Society for Antimicrobial Chemotherapy developed a MOOC on microbiology to cater education need in low- and middle-income countries, and found that 13% of participants were from Africa, 16% from Asia, 8% from Australia, 49%

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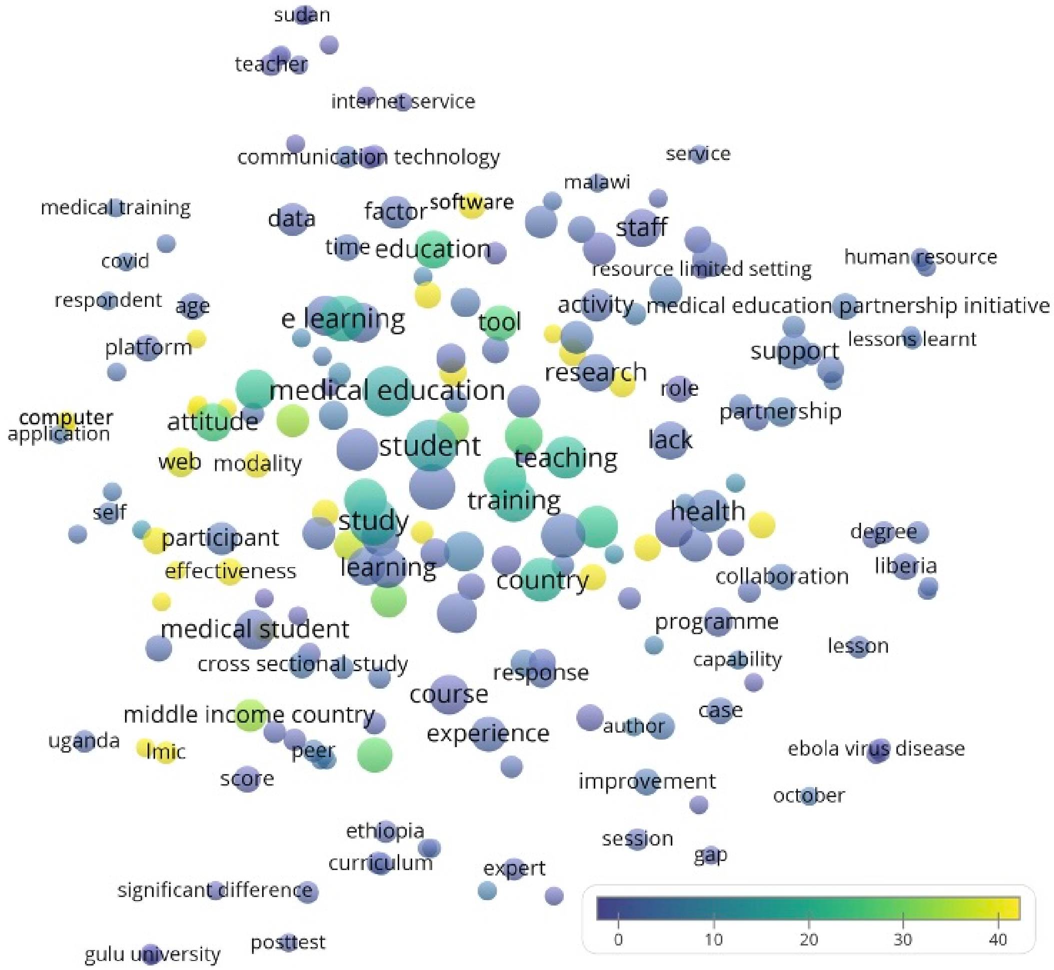
from Europe, 9% from North America, and 5% from South America [44].

Regarding publications with authors based in low-income economies according to the World Bank [22], we were able to identify a total of 29 publications from low-income economies with 262 citations, a CPP of 9.0, and an h-index of 7. A publication was included if it had an author based in low-income economies, irrespective of their position in the author list. The first document was published in 2009, an editorial that introduced a web-based learning environment by Omdurman Islamic University in Sudan [45]. The United States was involved in 8 (27%) of these 29 papers, whereas Sudan (n=7 [24%]), Ethiopia (n=6 [21%]), and Uganda (n=5 [17%]) were the most productive low-income countries. The most productive organization was Addis Ababa University in Ethiopia (n=5 [17%]), and the most productive journal was BMC Medical Education (n=3 [10%]). Figure 4 shows the recurring terms in the titles and abstracts (n≥2) from these publications. Terms reflected more basic concepts, such as resource-limited setting (n=2 [7%], CPP=0), computer (n=2 [7%], CPP=89.0), and medical education partnership initiative (n=4 [14%], CPP=5.0). Meanwhile, Table 2 shows that COVID-19 and training were recurring keywords shared by these papers and the entire data set.

Figure 4. Term map showing recurring terms from the titles and abstracts of the papers from low-income economies. Bubble colors indicate citations per publication, their size indicates frequency count, and their proximity indicates the frequency of their coappearance.



Discussion

Major Findings

This bibliometric analysis of 3978 publications on digital education research in medicine revealed that this field began to grow rapidly in terms of both publication and citation counts in the 2000s. Original articles accounted for 72.1% of the literature. The article-to-review ratio was 12:1. This ratio was higher than that for literature sets of virtual reality application in medicine (5.9:1) [21] and medical errors (8.1:1) [19]. This implied that researchers working in digital teaching in medical education tended to conduct original research and find novelty instead of summarizing evidence from existing literature. The literature had heavy contributions from North America, Europe, and Oceania. Low-income countries together accounted for 0.9% of the publications, and their works were infrequently cited. This situation was similar in the emergency medicine literature, for which low-income countries published only 0.1% of all articles [46]. The small contribution by low-income countries was also identified in cardiovascular [47] and anesthesia literature [48].

With the current COVID-19 pandemic, digital teaching could prove itself very beneficial for medical education. As a reflection of these benefits and the wide application of digital education

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during the pandemic, COVID-19 was the most frequently occurring author keyword in the analyzed literature data set (Table 2). During the COVID-19 pandemic, many reports were published to share the perspectives as well as the impact and challenges of a sudden switch to digital teaching in the local settings, such as in Malaysia [49], Jordan [50], and Saudi Arabia [51]. Importantly, not all populations can readily access the internet for digital teaching. In Jordan, a survey on 652 medical students found that the overall satisfaction rate in medical digital teaching was only 26.8%, because 69.1% of them faced a main challenge of internet streaming quality and coverage [50]. Based on a focus group interview of 60 students, medical students in Saudi Arabia also faced some internet connection and synchronicity issues, but digital teaching was well accepted overall [51]. In Europe, poor internet connection was encountered by only 21.5% of 2721 surveyed medical students [52]. Although digital teaching can take place in many formats, internet accessibility remains to be a mandatory requirement. In countries and regions where medical students cannot connect to the internet anytime and anywhere, perhaps asynchronous formats will be more suitable, such as a MOOC course. A MOOC course that teaches emergency medical practice may deliver the teaching with good student satisfaction and, at the same time, effectively reduce the cross-infection risk between teachers, clinical staff, medical students, and patients [53].

The following discussion covers the principal findings from the most cited original articles in the literature set. For instance, in the setting of problem-based learning (PBL), a blended version was found to be as effective as the traditional face-to-face approach in terms of test results; it was also significantly superior in terms of subjective learning gains and satisfaction with easy revisits to the web-based learning modules [54]. A similar study on learning acid-base physiology found that students not only had higher satisfaction regarding the web-based PBL compared with the traditional PBL, but also a significantly higher test score with a medium effect size [55]. Performance enhancement was similarly observed for basic life support learning with web-based virtual patient encounters over standard training [56]. Regarding the web tools, it was advocated that YouTube (YouTube LLC) could be a very useful platform to store and disseminate tailor-made teaching videos such as those dedicated to human anatomy [57]. Moreover, a learning period as short as 30 minutes with a mobile phone with augmented reality blended learning environment could already bring about a greater knowledge gain than a traditional textbook [58]. Another benefit of digital teaching was cost-effectiveness: it was estimated that blended learning could cut costs by 24% compared to the traditional face-to-face approach [59]. However, initial costs of creation and preparation of digital teaching tools, including provision of an adequate information technology environment, may exceed those of traditional face-to-face approaches and may therefore act as a possible barrier to implementation.

Taken together, this short overview of the most cited original articles in the analyzed literature set is illustrative of the diversity of digital tools that could be used for medical education and the benefits that they are offering.

To the authors' knowledge, no previous bibliometric analysis on digital teaching research in the medical literature has been published. A recent study on 10 e-learning journals found that the field shifted its foci from online learning, distance education, and pedagogical issues to mobile learning and interactive learning environments [60]. Meanwhile, research on e-learning in higher education was predominated by Spain and published in EDULEARN Proceedings [61]. These entities ranked 6th and 3rd in our predefined literature set, as listed in Table 1. By contrast, current results were consistent to a general e-learning literature analysis that identified the United States and the United Kingdom as the most productive countries; however, in both countries, chemical and engineering journals predominated instead of medical education ones [62,63]. Further, it was found that e-learning literature could be clustered into 7 foci: social sciences, psychology, medicine, health professions, life sciences, physical sciences or engineering, and computer science [64]. Moreover, it seemed that the contribution of computer science was on the decline whereas that of social sciences was gradually increasing in the scientific literature on digital education [65]. Finally, the current results were similar to that of the health sciences literature, where BMC Medical Education and Medical Teacher were the top 2 most productive journals, and COVID-19 was one of the most frequently mentioned keywords [66].

Limitations

Some papers might not be indexed by WoS and may thus be missed from the analysis presented in this study. Besides, it was not possible to assess the methodology and reporting quality of each experimental study due to the large number of publications involved. Moreover, the contributions from the low-income countries might be underestimated, as their works might be published in local journals or journals not indexed by WoS. This limitation could be partially addressed by extending the search to other databases such as Scopus and Education in Africa, hosted by AfricaBib. However, different databases count publication and citation data differently, which hinders merging such data for the kind of bibliometric analysis applied in our work. Nevertheless, readers should be aware that searching other databases with the same search string is expected to result in additional relevant publications (eg, identical PubMed search identified 5383 papers as compared with the 3978 papers identified in WoS, which was analyzed in this study) since WoS has more stringent requirements for indexing, requiring more time to achieve indexing for new journals. However, with respect to the latter consideration, it is a reasonable assumption that the most significant and impactful scientific works would be more often published in established journals already indexed in WoS (on average, the WoS data set analyzed by us consist of studies with higher significance and impact, and this is not necessarily a limitation; rather, it can also be seen as a kind of filtering that excludes papers from less established journals). Along this line of thought, we should however emphasize that "less established journals" would not necessarily imply inferior journal quality; while other databases sometimes index journals that simply do not meet the stringent quality criteria of WoS, at the same time, there are examples of newly emerging journals of high quality, which are well on their way to being indexed in WoS. One highly relevant example for this area of research

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would be JMIR Medical Education, edited by Nabil Zary, who was one of the most productive researchers identified in our study (Table 1). Furthermore, it should be noticed that the CPP data were based on all publication types, not just original articles. Therefore, a high CPP reflected in our study does not necessarily mean that only original research articles concerning certain terms were highly cited; this parameter is also influenced by the citation rates of relevant reviews, proceedings papers, editorial material, and meeting abstracts. Readers should be aware of these limitations when interpreting the results. Moreover, considering that Scopus and Google Scholar are becoming increasingly used for the assessment of academic performance in different environments (often in low- and middle-income countries), future studies assessing the publication practices based on these databases are expected to gain further insights.

Conclusions

The analyzed literature in the field of digital teaching research in medicine contained 3978 publications. The literature received worldwide contributions with the most productive countries being the United States and the United Kingdom. Reviews were significantly more cited, but the citations between OA vs non-OA papers did not significantly differ. Some themes were more highly cited, such as virtual reality, innovation, trial, effectiveness, and anatomy. Different aspects in medical education were experimented for digital teaching, such as gross anatomy education, histology, complementary medicine, medicinal chemistry, and basic life support. Some studies have shown that digital teaching could increase learning satisfaction, knowledge gain, and even cost-effectiveness. Digital teaching in medical education is expected to flourish in the future, especially in light of the COVID-19 pandemic occurrence, which brought the advantages of the digital education approach to the spotlight. This would be particularly useful for clinical teaching during pandemics, gaining insights into highly infectious diseases or rare diseases that do not have available cases in a local setting.

Conflicts of Interest

None declared.

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Abbreviations

CPP: citation per publication
MOOC: massive open online course
OA: open access
PBL: problem-based learning
WoS: Web of Science

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Viewpoint

Distributed Autonomous Organization of Learning: Future Structure for Health Professions Education Institutions

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Abstract

Current health professions education (HPE) institutions are based on an assembly-line hierarchical structure. The last decade has witnessed the advent of sophisticated networks allowing the exchange of information and educational assets. Blockchain provides an ideal data management framework that can support high-order applications such as learning systems and credentialing in an open and a distributed fashion. These system management characteristics enable the creation of a distributed autonomous organization of learning (DAOL). This new type of organization allows for the creation of decentralized adaptive competency curricula, simplification of credentialing and certification, leveling of information asymmetry among educational market stakeholders, assuring alignment with societal priorities, and supporting equity and transparency.

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KEYWORDS

blockchain; multidisciplinary; credentialing; medical education; health professionals; education; decentralization; training; curriculum; instruction

Health professions education (HPE) institutions are hierarchical structures designed to educate and train professionals using a model of education that is chronologically sequential and geographically restricted, and resembles an assembly line. Concurrent licensure, certification, and credentialing systems are also structured in the same rigid manner [1].

The past decade has witnessed the emergence of the knowledge economy, arising from a model appropriate for the manufacturing industry and evolving toward forming information-rich, adaptive, solution-oriented, network-based systems. This new tenet is based on the paradigms of open, distributed, decentralized, and scale-free networks [2].

The advent of complex network information systems and scalable data platforms has transformed information exchange and enabled the development of sophisticated networks, where goods, financial instruments, data, and information are handled. These scaffolds also support social media and learning networks [3]. Unfortunately, HPE organizations have neither developed nor embraced these new models.

One of the fundamental technologies powering modern information exchange networks is blockchain, which can be simply described as an open market of information where the origin and flow of assets can be traced openly, securely, and trustworthily [3].

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Blockchain can potentially provide a framework to support network-based knowledge management in HPE by allowing the creation, sharing, and usage of data that are distributed and stored simultaneously in warehouses open to all users. The inception, modification, and derivation of these data are possible for all members of the system, as all modifications to the system are clearly time stamped; authors are identified, and information is secured by advanced encryption. This creates a type of information that is reliable, traceable, and valid, with the ability to propagate rapidly and securely through communities of users [3]. Although blockchain appears ideal for information management, it is its ability to serve as the foundation of higher-order applications that is of paramount importance.

These blockchain-based systems enable the potential creation of the distributed autonomous organization of learning (DAOL) [4]. The DAOL constitutes a digital space where assets are negotiated autonomously and trustworthily. The DAOL can be conceptualized as a knowledge market, where goods (or digital assets such as a skill or credential) are interchanged when certain conditions are met (eg, course credit when an assessment threshold is achieved). These transactions occur automatically after prespecified conditions are met without human intermediaries or a central authority. The exchange of assets takes place using smart contracts, agreed upon by the participants of the organization before market transactions start. The contract execution is guaranteed by autonomous agents, which are algorithms that act as a digital notary for the market.

A DAOL for HPE would create a cascade of possibilities for curriculum development, licensing, certification, credentialing, and clinical practice.

First, the creation of DAOL systems will unbind disciplines (medicine, nursing, etc), institutions, locations, and time zones. Curricula will consist of a mesh of instructional modalities and microcredentialing badges creating a conceptual change from a cohorted, time-defined progression through a curricular path, leading to a progression that is nonlinear and not defined by time or location. HPE learners would be able to create adaptive learning objectives and curricula reflecting the specific knowledge and skills required for a particular job description rather than a general discipline (eg, emergency perfusionist instead of cardiac anesthesiologist specialized in extracorporeal oxygenation). This paradigm shift will likely lead to a pivot from the primacy of professional identity to a primacy of professional competency.

Second, the DAOL will allow the completion of these curricula in an automated manner once the learner has complied with the previously specified conditions (ie, smart contracts). These contracts will likely resemble entrustable professional activities mirroring clearly defined clinically based competencies. Governance of the system will rest on autonomous agents and not on human administrators or registrars, allowing faculty to focus on role modeling, coaching, assessment, and teaching clinical skills. Credentialing and licensing can be simplified, automatized, and made significantly less expensive. A DAOL system would make all necessary information open to all users; there will be no information asymmetry among players in the market.

Third, the DAOL creates a forum, through decentralized applications, for all stakeholders to participate in the design of the system. Patients, health care workers, government agencies, universities, and prospective employers would help elaborate curricula that are contextually relevant, continuously updated, and fit for purpose on communities. Existing reusable learning objects will be automatically validated, and where required, they could be created, adapted, and validated by others. At the same time, contractual conditions and requirements can be made explicit and automated, allowing for a job market that is more efficient, transparent, and equitable. This could create a learning system that reflects the diverse needs of societies throughout the world.

We believe that the DAOL constitutes a new educational exchange structure that supports the construction and validation of knowledge, and the creation of a modern learning management system. This framework allows for a new paradigm for HPE that is distributed, open, and valid, with profound implications for curriculum development, licensing, certification, credentialing, contracts, and clinical practice. The DAOL might be the answer to the calls for reimagining the future structure of HPE.

Conflicts of Interest

None declared.

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Abbreviations

DAOL: distributed autonomous organization of learning
HPE: health professions education

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Original Paper

Comparing Web-Based and In-Person Educational Workshops for Canadian Occupational Therapists and Understanding Their Learning Experiences: Mixed Methods Study

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Abstract

Background: The Do-Live-Well (DLW) framework is an occupation-focused health promotion approach. Occupational therapists (OTs) have been interested in training opportunities regarding this framework. Traditionally, in-person continuing educational interventions are the main way that OTs obtain knowledge, but web-based learning has become popular among health care professionals. However, its effectiveness and learners' experience in web-based learning have not been well-studied in occupational therapy education.

Objective: This study aims to evaluate the effectiveness of the web-based and in-person educational DLW workshops for Canadian OTs and to understand their experiences in both workshop types.

Methods: An explanatory sequential mixed methods study design was used, where quantitative data were collected first, then qualitative data were used to explain the quantitative findings. A quasi-experimental design and interpretative description methodology were used in the quantitative and qualitative phases, respectively.

Results: Quantitative results were as follows: a total of 43 OTs completed pre-, post-, and follow-up evaluations (in-person group: 21/43, 49%; web-based group: 22/43, 51%). Practice settings of the participants varied, including geriatric, hospital, long-term, mental health, pediatric, and primary settings. The primary outcome was as follows: there were no statistically significant differences in knowledge changes at the 3 time points (P=.57 to P=.99) between the groups. In the web-based group, the knowledge scores at follow-up were lower compared with the posttest results, meaning that knowledge gain was reduced over time (P=.001). The secondary outcomes were as follows: there were statistically significant differences between the groups in factors influencing DLW adoption at posttest (P=.001) and in satisfaction with the workshop (P<.001) at posttest in favor of the in-person group. Qualitative results were as follows: a total of 18 OTs (9/18, 50% from each group) participated in an individual interview. Five themes were identified regarding learners' workshop experiences: relevance to their practices and interests may improve learning, a familiar learning environment may facilitate learning, synchronous in-person interaction is valuable in the learning process, ease of access to learning should be considered, and flexibility in web-based learning can be both beneficial and challenging.

Conclusions: The quantitative results of this study reported no difference in knowledge acquisition between the in-person and web-based groups, indicating that web-based education is as effective as in-person workshops. However, participants' satisfaction with the workshop was statistically significantly higher for the in-person workshop. The qualitative findings described the participants' perceived benefits and challenges of each educational format. The participants in both the web-based and in-person workshop groups valued in-person interactions in learning, but the participants in the web-based workshop group expressed web-based learning lacked in-person-like interactions. Thus, adding synchronous in-person interactions to web-based learning may improve learners' educational experiences in web-based occupational therapy and continuing education.

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KEYWORDS

online education; occupational therapy; occupational therapist; continuing education

Introduction

Background

Each day, human beings engage in various occupations, defined as sets of activities for purposes, such as self-care, leisure, and productivity that are a core concept of occupational therapy [1]. Occupation-focused frameworks are used by occupational therapists (OTs) to understand occupational issues, enabling the provision of services that are responsive to the needs and goals of the clients [2]. The Do-Live-Well (DLW) framework is an evidence-based Canadian health promotion approach developed by OTs [3]. The key message of the DLW framework is that engaging in daily patterns of activity that allow for an optimal range of experiences with sufficient personal and social support can lead to a wide range of positive health and well-being outcomes [3]. Despite interest in this relatively new framework from OTs around the world, continuing education to support the adoption of the framework in practice has been limited to only certain areas of Canada, including Quebec and Ontario. On the basis of requests nationally and internationally, the developers of the framework identified a need to provide educational opportunities to meet these expanding learning needs.

The importance of health care professionals engaging in continuing education activities to advance their professional knowledge and expertise has long been emphasized [4]. OTs have used continuing education as a primary resource to maintain and improve their knowledge, ensure clinical competency, and pursue personal development [5,6]. The importance of continuing education in occupational therapy practice has been addressed in literature [7-9]. Although the most common type of continuing education for OTs is through in-person delivery methods such as conferences, presentations, and seminars or workshops [6], web-based education has become increasingly popular in health care professions across the world [4].

In this study, the term *web-based learning* was defined as "learning experiences via the use of some technology" [10]. Although cultural and technological adaptations are required to implement web-based learning [11,12], the advantages of this web-based delivery modality have been shown in health professional education, such as easy accessibility to learning without geographical restrictions, customized learning pace, and multimedia use [11-14]. In particular, the COVID-19 outbreak in December 2019, leading to public health restrictions through 2020 and 2021, has dramatically changed the means of delivering knowledge from traditional in-person learning to web-based methods [15]. This indicates that web-based learning is no longer simply an option but rather an essential educational delivery route. Although the importance and availability of web-based education in occupational therapy has been emerging since the beginning of the 21st century [16], the effectiveness of web-based education as a continuing educational opportunity compared with in-person education for OTs has not been well-studied. A systematic review comparing the effectiveness of web-based and traditional in-person learning reported little or no difference in the knowledge, behavioral changes, or skills of health professionals [17]. However, these results may not be definitively generalized to occupational therapy education because only a small proportion of study participants were OTs (only 8% to 11% of OTs in one randomized controlled trial) [17]. Furthermore, although the existing studies provide quantitative results in terms of the effectiveness of web-based and in-person learning, they lack an understanding of how the participants experienced these educational delivery methods. This understanding of what does or does not work well in both educational methods may help educators in occupational therapy improve future learning environments. Thus, research is needed to compare the effectiveness of web-based and in-person education delivery methods and to understand the learning experiences of the participants in continuing occupational therapy education.

Objectives

The objective of this study is to compare the effectiveness of a web-based DLW workshop with an in-person model for Canadian OTs and to understand the learners' experience of participating in both web-based and in-person workshops. The primary research questions of this study are as follows: *What is the effectiveness of the web-based DLW workshop compared with the in-person DLW workshop?* and *What are the perceived benefits and challenges of participating in both educational delivery methods?*

Methods

Study Design

Overview

This study was approved by the Hamilton Integrated Research Ethics Board (Project 4114). An explanatory sequential mixed methods study design was used to evaluate the effectiveness of web-based and in-person DLW workshops and to understand the experiences of the participants in learning about the framework [18]. This study consisted of 2 phases, in which quantitative data were collected first and then qualitative data were used to expand on the findings from the quantitative data. A visual diagram of the study process is presented in Figure 1.

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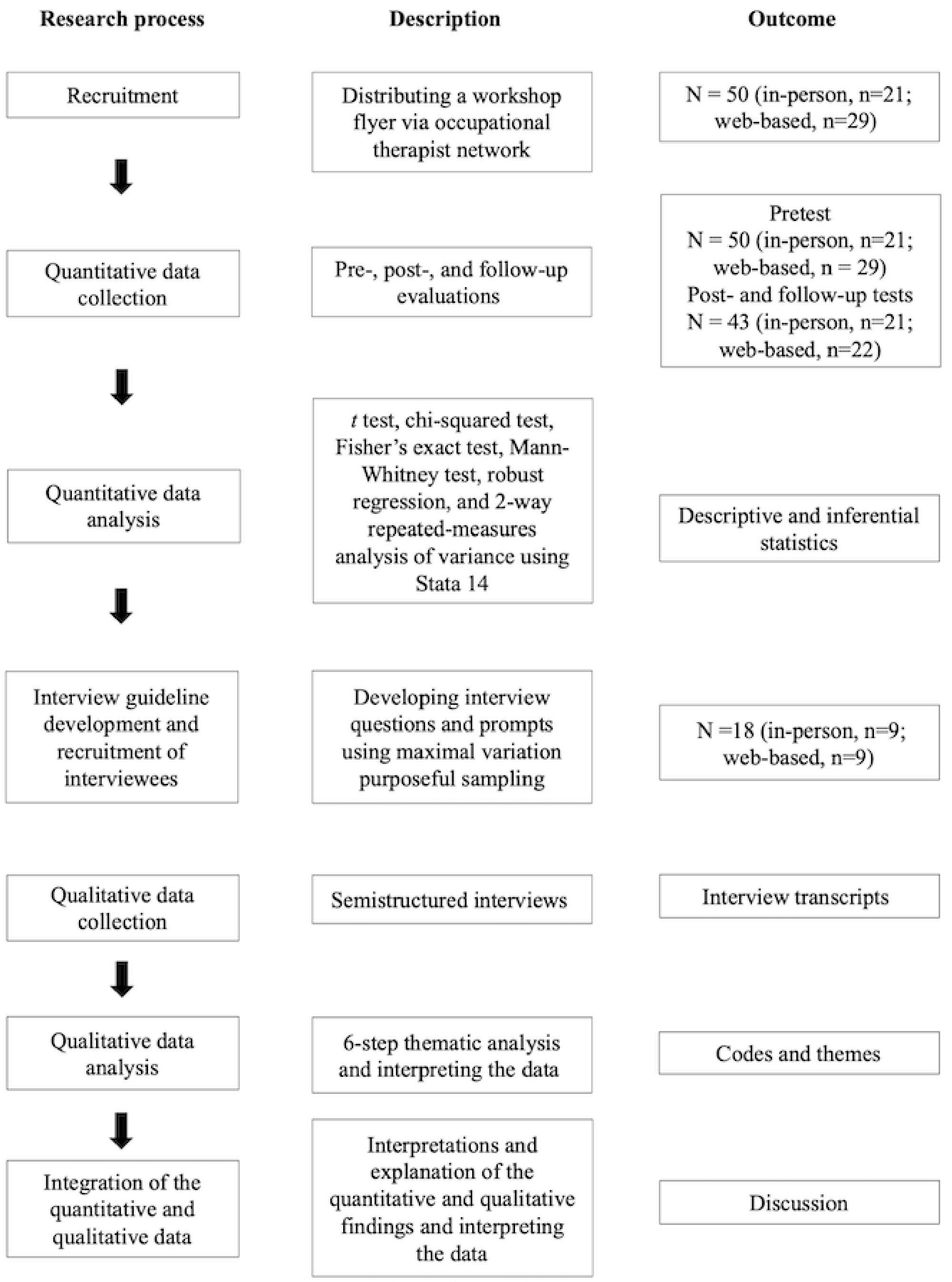
Figure 1. Overview of the study design, including the research process, description, and outcome for each stage.



Quantitative Phase

A pre-, post-, and follow-up quasi-experimental design was used to compare the immediate and subsequent outcomes of the web-based workshop with those of the in-person workshop. Participants were not randomly assigned because of geographical limitations.

Qualitative Phase

An interpretative description approach [19] was used to understand the learners' perceived benefits and challenges of participating in the workshops. Interpretative description was considered appropriate for use because it allows for a flexible approach to capturing the experiences of the participants and for researchers to apply research findings to practice [19].

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Participants

Quantitative Phase

Participants were Canadian OTs who were offered to attend either the web-based or in-person DLW workshop, and they selected one of the learning formats to attend. We recruited participants by distributing a research flyer via Canadian OT communities and offered the workshop free of charge as part of the study participation. Canadian OTs practicing in any setting were eligible to participate in this study because the DLW framework is designed to be applied to people of any age, health condition, capacities, and occupational challenges. The total target sample size was 51; this estimate was based on an expected effect size of 0.9 gain in knowledge [20], where a power of 0.8, α of .05, and a 20% dropout rate were applied. A workshop flyer was posted on the Canadian Association of Occupational Therapists website, and the DLW team members shared the flyer with colleagues in their network to recruit eligible participants.

Qualitative Phase

Although there are no guidelines for calculating sample size in qualitative research [21], and interpretative description can be performed with almost any sample size [19], it is recommended to have at least 12 participants to reach data saturation in this type of design [22]. We recruited web-based and in-person workshop participants for a semistructured, 1:1 interview. We sent an invitation to all workshop participants via email to seek participation in an interview 3 months after the workshop. We hoped that we would gain various perspectives from participants in different clinical settings who used the DLW framework to varying degrees regardless of their education, work experience, and gender [23].

Workshop Description

Both the web-based and in-person workshops consisted of 4 sessions (the schedule is shown in Textbox 1). Workshop content was scripted to ensure that both web-based and in-person workshops delivered the same content. The in-person workshop was a single-day, 8-hour workshop, and the web-based workshop was planned to last 4 weeks, also taking approximately 8 hours. A problem-based learning (PBL) approach was incorporated to facilitate a learner-centered learning environment for both formats. For example, participants in both workshops were divided into 5 groups according to the case scenario they chose, and they had a chance to answer reflective questions through discussions. Each group in the in-person workshop watched the video case scenario assigned to them in a separate space. To meet the purpose of this study, we limited the interactions provided in the web-based workshop to asynchronous components, recognizing that synchronous activities using technology are possible, but this was not the focus of our study. Although the web-based workshop was asynchronous and prerecorded, asynchronous discussion forums were provided on the web to give learners an opportunity to interact and share their perspectives with one another as well as with educators with expertise in the DLW framework. The DLW team members monitored both web-based and in-person group discussions and answered questions raised during the discussions. Although the learners in the in-person workshop could immediately hear the answers to their questions, the web-based learners could not receive immediate answers to their questions because of the nature of asynchronous web-based learning. Participants in the in-person group received a printed workbook, whereas the web-based group could download the same content electronically. The details of the workshop development process are described elsewhere [24].

Textbox 1. Workshop schedule.

Introducing instructors, participants, and learning and teaching approach

- Session 1
  - Introducing case scenarios
  - Health promotion and health and well-being outcomes
- Session 2
  - Introduction of the Do-Live-Well framework
  - Dimensions of activity
- Session 3
  - Activity patterns
  - Social and personal support
- Session 4
  - Application of the Do-Live-Well framework
  - Large group case scenario discussions
- Wrapping up
  - Question and answer and reflection
  - Postevaluation

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Data Collection

Quantitative Phase

We developed the pre- (Multimedia Appendix 1), post- (Multimedia Appendix 2), and follow-up (Multimedia Appendix 3) questionnaires specifically for this study through a literature review and consultation with 4 occupational therapy research experts from the DLW research team. The purpose of the consultation was to ensure that the appropriate questions were included to measure the workshop outcomes. Three levels of the training evaluation model by Kirkpatrick and Kirkpatrick, including reaction, learning, and behavior, were used to decide on the content of the questionnaires [25]. The questionnaires at each time point consisted of slightly different content packages (Textbox 2) but aimed to capture a comprehensive understanding of the effectiveness of the workshop. We incorporated the key constructs of the diffusion of innovation model [26] into the questionnaire, particularly for questions about factors influencing DLW adoption. This was intended to ensure a comprehensive evaluation of the appropriate parameters to determine the potential for adopting the DLW framework among OTs. The diffusion of innovation model explains how new knowledge (innovation) is disseminated in a certain social system over time, and the main constructs used are attributes of innovation, communication channels, and the social system [26]. After developing the initial versions of the questionnaires, the researchers pretested them qualitatively with 4 graduate students in the rehabilitation science program at McMaster University. The questionnaires were refined based on the feedback from the students and discussions with the DLW research team members. For example, the level of knowledge questions was adjusted, and more detailed instructions were added.

Textbox 2. Questionnaire content.

Pretest

- Part 1: background information about the participant
- Part 2: current status of the use of the Do-Live-Well (DLW) framework
- Part 3: factors influencing DLW adoption
- Part 4: knowledge questions

Posttest

- Part 1: factors influencing DLW adoption
- Part 2: knowledge questions
- Part 3: satisfaction with the workshop

Follow-up test

- Part 1: current status of the use of the DLW framework
- Part 2: factors influencing DLW adoption
- Part 3: knowledge questions

Primary Outcome

The primary outcome was knowledge of the DLW framework. The DLW research team tested how much the participants knew about the DLW framework at 3 time points (pre-, post-, and 3-month follow-up) through 2 multiple-choice questions and 8 true-or-false questions. Each question had a value of 1 point for a correct answer; if a respondent answered all questions correctly, they earned 10 points. The participants were asked to complete the preworkshop questionnaire 1 week before the workshop to evaluate their baseline level of knowledge of the DLW framework. The participants then were required to complete the postworkshop questionnaire immediately following the workshop, and 3 months after the workshop the participants were asked to complete the follow-up questionnaire.

Secondary Outcomes

The secondary outcomes included the following: (1) changes in factors influencing DLW adoption, (2) satisfaction with the workshops, and (3) current use of the DLW framework. For factors influencing DLW adoption, the questions asked were about the advantages, compatibility, complexity, trialability, and observability of DLW use [26]. The participants also evaluated their communication channels, social system, and intentions for DLW use. All participants were asked to complete their evaluations at 3 time points (pre, post, and 3-month follow-up). The questionnaire included 10 questions, a 6-level Likert scale (1=strongly disagree to 6=strongly agree), and the total score ranged from 10 to 60. The core ideas of the questionnaire were the same for the pre-, post-, and follow-up questionnaires, with the exception of 1 question regarding the participants' desire to apply the DLW framework that was removed for the follow-up test. The participants were asked to score their satisfaction with their workshop experience immediately after the workshop. The satisfaction questionnaire consisted of 16 questions, with a Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree), and its total score ranged from 16 to 112. The following are some of the example questions that were included: the accessibility of the workshop was convenient, the learning environment encouraged me to actively participate in learning, and the time frame of the

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workshop was appropriate. Finally, the participants were asked about their current use of the DLW framework by answering a *yes or no* question in both the pretest and follow-up questionnaires. They were also asked about the frequency with which they had used the DLW framework with their clients and at an organizational level, where 0 indicated *never use it* and 10 indicated *use it all the time*.

Qualitative Phase

The first author (SK) developed the qualitative interview guide based on the findings from the follow-up quantitative data analysis. The goal of this qualitative phase was to understand what worked well and what did not work well for participants in both learning formats by acquiring a comprehensive understanding of the participants' learning experiences. The interview questions focused on exploring the experiences of each participant in the workshop, including facilitators and challenges of participating in the workshop and engaging with the workshop content, as well as recommendations for future workshops. Each interview lasted 40-60 minutes. Owing to the COVID-19 pandemic, all participants were interviewed on the web using the videoconferencing platform Zoom. The interviews were audio- and video-recorded with the consent of the participants.

Data Analysis

Quantitative Phase

All statistical analyses were conducted using Stata version 14 (StataCorp) [27]. Descriptive statistics were generated to present the characteristics of the participants and the variables of interest. The 2-tailed *t* test was used to find the differences in the mean total scores of the normally distributed variables between the 2 groups. If the variable was not normally distributed, the Wilcoxon-Mann-Whitney test was conducted. To find differences in categorical variables between the 2 groups, the chi-square test was used, and the Fisher exact test was applied in the analysis of small samples. Robust regression was conducted as an alternative to the analysis of covariate and linear regression because of the violation of normality and homogeneity of variance assumptions, respectively. Any statistically significant differences over time in the variables was found using 2-way repeated-measures analysis of variance.

Qualitative Phase

The interviews were transcribed verbatim by the first author (SK), and data analyses were supported using NVivo 12 (QSR International) [28]. We followed the 6-step analytical process described by Braun and Clarke [29]. This process included the following: familiarizing with the data through repeated readings, developing codes, grouping codes into themes, reviewing themes, generating definitions and names of the themes, and writing a report [29]. The first author read all transcripts several times and immersed herself in the data. Then, she generated initial codes relevant to the primary goal of the qualitative phase, which was to understand the benefits and challenges of participating in a web-based or in-person workshop. When generating the themes, the researchers realized that participants in both groups had some experience with both formats, although not in the DLW workshop. For example, participants in the web-based group had prior experience with in-person learning and shared various perspectives on the benefits and challenges of participating in both formats. Thus, rather than generating themes comparing the experiences of participants in the web-based and in-person workshop, we generated themes describing the comprehensive perspectives and experiences of the participants regarding both formats. The first author then presented the data analysis process and reported the initial themes to the research team. The themes were refined and finalized through discussions among the research team.

To establish the credibility of the findings, the first author wrote reflective notes for each interview participant and discussed with the research team whether the identified themes answered the research questions [30]. Furthermore, detailed descriptions of the research methods were provided to ensure the dependability of the qualitative findings [30].

Results

Quantitative Data: Participant Characteristics

Initially, 50 OTs agreed to participate in the study (in-person group: 21/50, 42%; web-based group: 29/50, 58%). In total, 6 participants did not complete both the post- and follow-up evaluations. One participant did not complete the postevaluation, and another participant did not complete the follow-up evaluation. Because all evaluations were performed anonymously, it was impossible to personally contact those who did not complete the post- and follow-up evaluations to ask them why they did not complete the evaluations. Although we sent multiple emails to remind the participants of the evaluations, no one sent an email stating that they could not complete the evaluations. Thus, data comparing 21 in-person and 22 web-based workshop participants have been presented. There was no statistically significant difference in demographic characteristics between the 2 groups. The detailed characteristics of the participants are presented in Table 1.

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Table 1. Participant characteristics.

Variables	In-person (n=21)	Web-based	Total	*P* value
Age (years), mean (SD)	39.29 (11.1)	38.3 (9.70)[a]	38.79 (10.32)[b]	.86
Sex, n (%)	21 (100)	22 (100)	43 (100)	.99
Female	21 (100)	21 (95)	42 (98)	
Male	0 (0)	1 (5)	1 (2)	
Education level, n (%)	21 (100)	29 (100)	50 (100)	.74
BScOT[c]	4 (19)	7 (24)	11 (22)	
MScOT[d]	17 (81)	22 (76)	39 (78)	
Overall years of experience as an occupational therapist, mean (SD)	13 (11.73)	12.46 (8.64)	12.69 (9.94)	.80
Years of practice in the current setting, mean (SD)	8.28 (9.89)	6.26 (6.33)	7.11 (7.99)	.64
Resources used to learn about DLW[e] before the workshop, n (%)	21 (100)	29 (100)	50 (100)	.05
Journal	0 (0)	1 (3)	1 (2)	
Lecture	1 (5)	2 (7)	3 (6)	
Website	8 (38)	8 (28)	16 (32)	
>1 of the above	6 (29)	2 (7)	8 (16)	
None of the above	6 (29)	15 (52)	21 (42)	
Practice setting, n (%)	21 (100)	29 (100)	50 (100)	.46
Geriatric	1 (5)	3 (10)	4 (8)	
Hospital	1 (5)	3 (10)	4 (8)	
Long-term	1 (5)	1 (3)	2 (4)	
Mental	10 (48)	8 (28)	18 (36)	
Pediatric	1 (5)	2 (7)	3 (6)	
Primary	3 (14)	3 (10)	6 (12)	
Private	1 (5)	0 (0)	1 (2)	
None of the above	2 (10)	9 (31)	11 (22)	
Preference, n (%)	21 (100)	29 (100)	50 (100)	.65
In-person	17 (80)	20 (69)	37 (74)	
Web-based	2 (10)	6 (21)	8 (16)	
None	2 (10)	3 (10)	5 (10)	
Use of the DLW in practice, n (%)	21 (100)	29 (100)	50 (100)	.17
Yes	2 (10)	0 (0)	2 (4)	
No	19 (90)	29 (100)	48 (96)	

[a]n=22.

[b]N=43.

[c]BScOT: Bachelor of Science in Occupational Therapy.

[d]MScOT: Master of Science in Occupational Therapy.

[e]DLW: Do-Live-Well.

Quantitative Data: Primary Outcome

Effects of the Workshops on Knowledge Regarding the DLW Framework

At baseline, the in-person group (n=21) reported a mean of 5.48 (SD 1.75) out of 10 on their knowledge of the DLW framework, whereas the web-based group (n=29) reported a mean of 5.39 (SD 1.69) out of 10, meaning the participants knew approximately half of the core concepts of the DLW framework that were tested in the knowledge questionnaire. The *t* test showed no statistically significant difference between the groups at baseline (*P*=.87).

Immediately following the workshop, the participants who attended the in-person workshop reported a mean of 7.62 (SD

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0.22) of 10, whereas the participants in the web-based workshop reported a mean of 7.81 (SD 0.27) of 10. There was no statistically significant difference in knowledge regarding the DLW framework between the 2 groups immediately following the workshop (*P*=.57).

Similarly, at the follow-up evaluation, there was no statistically significant difference in knowledge regarding the DLW framework between the groups (*P*=.99). The in-person group reported a mean of 7.05 (SD 1.12) of 10 and the web-based group had a mean of 6.77 (SD 1.80) of 10.

Regarding the knowledge differences over time between the web-based and in-person workshops, the Mauchly test of sphericity validated the use of the 2-way repeated-measures analysis of variance (*P*=.63). There was no statistically significant interaction between the type of workshop and time regarding knowledge of the DLW framework ($F_{2,48}$=0.90; *P*=.41). The main effect for the workshop type was not statistically significant ($F_{1,48}$=0.15; *P*=.70), meaning that there was no difference in knowledge means between the in-person and web-based groups over time. In contrast, there was a significant main effect for time ($F_{2,48}$=40; *P*<.001). The pairwise comparisons indicated that, in the in-person group, the knowledge change was reported between the pretest and posttest (contrast=2.14, 95% CI 1.42-2.87; *P*<.001), meaning that knowledge improved immediately following the workshop. In addition, knowledge improved in follow-up evaluations compared with preworkshop knowledge (contrast=1.57, 95% CI 0.84-2.30; *P*<.001). This result revealed an improvement in knowledge regarding the DLW framework at the post- and follow-up evaluations when compared with the baseline scores. In contrast, there was no knowledge change between the posttest and follow-up test (contrast=−0.57, 95% CI −1.30 to 0.16; *P*=.12), which means that knowledge remained the same 3 months after the workshop.

In the web-based group, there was a knowledge change between the pretest and posttest (contrast=2.42, 95% CI 1.70-3.14; *P*<.001), between the pretest and follow-up test (contrast=1.16, 95% CI 0.44-1.88; *P*=.002), and between the posttest and follow-up test (contrast=−1.26, 95% CI −1.97 to −0.54; *P*=.001). Knowledge improved at both the posttest and follow-up evaluations compared with the pretest results. However, the knowledge scores at the follow-up evaluations were lower compared with the posttest results, which means that there was some reduction in knowledge gains over time.

Quantitative Data: Secondary Outcomes

Effects of the Workshops on the Factors Influencing DLW Adoption

Unlike in the knowledge questionnaire, a lower score for the factors influencing DLW adoption did not indicate a wrong answer. Instead, it indicated the degree to which the participants disagreed with the statements in the questionnaire and perceived their capacity to adopt the DLW framework in practice; a higher score meant that the participants were more likely to use the DLW framework in their practice. The mean total score of the pretest for the factors influencing the application of the DLW framework in practice was 38.24 (SD 5.19) out of 60 for the in-person group and 33.82 (SD 6.05) out of 60 for the web-based group. This represented a statistically significant difference using a *t* test between the 2 groups in terms of the factors influencing the application of the DLW framework in practice (*P*=.01). The participants in the in-person group showed higher scores for all questions regarding influencing factors, indicating more positive perceptions of their situations that would support the adoption of the DLW in their practices. Both groups presented the lowest score on the question about how much the participants knew about the DLW framework (in-person=1.95, web-based=1.39), and the highest score was on their willingness to use the DLW framework in practice (in-person=4.9, web-based=4.76). A pretest was conducted before the participants took the DLW workshops, and both groups scored low in terms of their knowledge of the DLW framework, confidence in using it, and how well they knew the resources and experts that would help them understand the DLW framework. The participants felt that the DLW framework would be beneficial in their practice and improve the health outcomes of their clients. They also believed that the DLW framework would fit well in their practice and be easy to apply, and that coworkers would support their use of the DLW framework. The question about how much the participants knew about the DLW resources presented the largest difference in mean scores between the 2 groups. The question about whether the DLW framework would be beneficial in their practice presented the smallest gap between the 2 groups.

Immediately following the completion of the workshop, the mean total score for the factors influencing the use of the new knowledge in practice was 52.10 (SD 4.89) and 43.82 (SD 8.16) out of a maximum score of 60 in the in-person and web-based groups, respectively. Because there was a statistically significant baseline difference in the factors influencing the adoption of the DLW framework between the 2 groups (*P*=.01), the robust regression procedure was conducted using the pretest result as a covariate. The independent variables were the group and the mean total score at pretest, and the dependent variable was the mean total score at posttest. The robust regression result still presented a statistically significant group difference ($F_{2,39}$=13.98; R^2=0.5094; *P*=.001) after controlling for the covariate, and the participants in the in-person group presented higher scores on each item of the questionnaire. The in-person group scored an average of 5.17 more points than the web-based group after controlling for the pretest results as a covariate (Table 2).

Compared with the pretest results, both groups had increased scores for every question, except that the participants in the web-based group scored lower on the question regarding how easy it would be to apply the DLW framework in practice. Specifically, both groups presented a large increase in the questions about their knowledge of the DLW framework, confidence in its use, and the extent of their knowledge of its resources and experts compared with the pretest results.

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Table 2. Robust regression of posttest for factors influencing Do-Live-Well framework adoption.

Variable	B^a (robust SE; 95% CI)	*t* test (*df*)	*P*>|*t*|	*F* test (*df*)	R^2
Group	−5.17 (1.48; −8.16 to −2.18)	−3.49 (40)	.001	—[b]	—
Pretest	0.65 (0.14; 0.37 to 0.93)	4.71 (40)	<.001	—	—
Constant	27.09 (5.31; 16.36 to 37.82)	5.11 (40)	<.001	13.98 (2,39)	0.5094

[a]Regression coefficient.

[b]Not available.

The in-person group presented the highest score on the question regarding their willingness to use the DLW framework and the lowest score on the question regarding their confidence in using the DLW framework in their practice. The web-based group presented the highest score on the question regarding the benefit of the DLW framework and the lowest score on the question regarding the ease of using the DLW framework in their practice.

The largest difference between the groups was the question about how well they knew DLW experts; in other words, compared with the web-based group, the participants in the in-person group felt they knew the DLW experts better.

Three months after the workshop, at the follow-up evaluation of the factors influencing the adoption of the DLW framework, the in-person group presented a mean total score of 39.62 (SD 8.24), whereas the web-based group reported a mean total score of 34.77 (SD 8.72) of a maximum score of 60, respectively. The participants in the in-person group scored higher in all items, similar to the pre- and posttest results.

Robust regression was also performed, and no statistically significant difference was noted between the groups after controlling for the covariate ($F_{2,39}$=1.69; R^2=0.14; *P*=.19; Table 3). The in-person group presented the highest score on the question regarding their belief in the positive impact of the DLW framework for the health outcomes of their clients and the lowest score on the question about their confidence in using the DLW framework in their practice. The web-based group presented the highest score on the question about their accessibility in the DLW resources and the lowest score on the question about the support of their colleagues in DLW applications.

Both groups presented decreased scores on every question compared with the posttest. The difference in the total mean score of the questions between the 2 groups mostly became smaller compared with the posttest, except for the questions about the benefit of the DLW framework in practice and the support of colleagues in its use. The largest difference between the groups was evident in the question about whether their colleagues would support their DLW application. In other words, the in-person group felt more positive about the support of their colleagues in the DLW application. The smallest difference between the groups was regarding the question about the confidence of the participants in the DLW application; the in-person group's follow-up scores decreased compared with the posttest results. Throughout all phases (pre-, post-, and follow-up tests), the in-person group presented higher scores for all questions about the factors influencing DLW adoption.

Table 3. Robust regression of follow-up results for factors influencing Do-Live-Well framework adoption.

Variable	B^a (robust SE; 95% CI)	*t* test (*df*)	*P*>|*t*|	*F* test (*df*)	R^2
Group	−2.73 (2.06; −6.90 to 1.45)	−1.32 (40)	.19	—[b]	—
Pretest	0.44 (0.28; −0.13 to 1.00)	1.56 (40)	.13	—	—
Constant	25.34 (7.85; 9.47 to 41.21)	3.23 (40)	.003	1.69 (2,39)	0.14

[a]Regression coefficient.

[b]Not available.

Satisfaction With the Workshops

Immediately following the workshop, the participants in the in-person group were more positive in their appraisal of the workshop (mean total score 106.38, SD 6.73) than the web-based group (mean total score 90.77, SD 16.11). The Mann-Whitney test showed a statistically significant difference between the groups in their satisfaction with the workshop (*P*<.001). The participants in the in-person group scored higher on all items asking about their satisfaction with the workshop. The in-person group was most satisfied with the skills of the instructors in encouraging participant-engagement and least satisfied with the constructive feedback of the instructors.

The web-based group was most satisfied with the accessibility of the learning method and least satisfied with the constructive feedback of the instructors. The largest difference between the groups was regarding the question about the learning environment in favor of the in-person group, and the smallest difference between the groups was with regards to the question about the accessibility of learning.

Effects of the Workshops on DLW Application After the Workshops

Three months after the workshop, 43% (9/21) of the people in the in-person group said they had been using the DLW framework. In the web-based group, 27% (6/22) said they had

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been using the DLW framework. The chi-square test revealed no statistically significant difference in the use of the framework after the workshop (χ^2_1=1.2; *P*=.28). The clinical practices of the 15 OTs applying DLW concepts from both groups were as follows: mental health (in-person group: 5/6, 83%; web-based group: 1/6, 17%); primary care (in-person group: 2/4, 50%; web-based group: 2/4, 50%); accessibility service (in-person group: 1/1, 100%); pediatrics (web-based group: 1/1, 100%); and private setting (in-person group: 1/1, 100%).

The mean frequency of the DLW framework use with clients was 2.62 (SD 2.54) for the in-person group (n=21) and 1.59 (SD 2.13) for the web-based group (n=22) on a frequency scale of 0-10. The Mann-Whitney test showed no statistically significant difference between the groups (*P*=.13). Regarding the OTs' frequency of use of the DLW framework other than for their clients (in-person, n=21: mean=2.71/10, SD 2.47; web-based, n=22: mean=1.95/10, SD 2.30), there was no statistically significant difference between the groups (*P*=.22). The results for all outcomes at the 3 time points are presented in Table 4.

Table 4. Mean scores for the primary and secondary outcomes at the 3 time points.

Outcomes	Pretest			Posttest			Follow-up test		
	In-person (n=21), mean (SD)	Web-based (n=29), mean (SD)	*P* value	In-person (n=21), mean (SD)	Web-based (n=22), mean (SD)	*P* value	In-person (n=21), mean (SD)	Web-based (n=22), mean (SD)	*P* value
Knowledge regarding DLW[a]	5.48 (1.75)	5.39 (1.69)	.87	7.62 (0.22)	7.81 (0.27)	.57	7.05 (1.12)	6.77 (1.80)	.99
Factors influencing DLW adoption	38.24 (5.19)	33.82 (6.05)	.01	52.10 (4.89)	43.82 (8.16)	.001	39.62 (8.24)	34.77 (8.72)	.19
Reaction to the workshop	N/A[b]	N/A	N/A	106.38 (6.73)	90.77 (16.11)	<.001	N/A	N/A	N/A
Use			.17	N/A	N/A	N/A			.28
Yes	2	0					9	6	
No	19	29					12	16	
Use with clients (0-10)	N/A	N/A	N/A	N/A	N/A	N/A	2.62 (2.54)	1.59 (2.13)	.13
Use at an organizational level (0-10)	N/A	N/A	N/A	N/A	N/A	N/A	2.71 (2.47)	1.95 (2.30)	.22

[a]DLW: Do-Live-Well.

[b]N/A: not applicable.

Qualitative Data

Participant Characteristics

In total, 18 OTs (9/18, 50% from each group), including 1 man and 17 women, participated in an individual interview an average of 14 weeks after the end of their workshop participation. Their mean age was 39.56 (SD 9.95) years, and their mean work experience was 13.44 (SD 9.57) years. Of the 18 OTs, 4 (22%) had a bachelor's degree, and 14 (73%) had a master's degree in Occupational Therapy. From a total of 18 OTs, 10 (56%) applied the DLW framework in their practice, and 8 (44%) did not use it. Their practice settings were as follows: mental health (6/18, 33%), primary care (2/18, 11%), hospital (2/18, 11%), and others (8/18, 44%), including education, long-term care, ophthalmology clinics, pediatric, accessibility, private practices, rehabilitation units, and veterans' centers.

Five themes from the ideas that were discussed frequently were identified in relation to the OTs' experience of participating in web-based and in-person workshops, focusing on its facilitators and challenges.

Theme 1: Relevance to One's Practice and Interests May Improve Learning

Participants seemed to engage in learning better when the content was relevant to their practice or interests. In both the web-based and in-person workshops, the learners were able to choose the *case scenario* that was relevant to their practice or interest. Being able to choose the case scenario increased the learners' motivation. In this regard, one participant in the web-based group said as follows:

> *I like the fact that I could choose one that was relevant, I think I would have a much harder time obviously with a setting or a population that I am not familiar with. So that was a nice way to learn.* [Interviewee 18]

In addition, some participants seemed to like *discussions or conversations that were directly related to their practice or interests*. Some found that a downside of the in-person workshop was listening to conversations that were not directly related to their practice or interests. Unlike web-based learning, where people could freely choose what to read based on their interests, people in the in-person workshop had to sit down and listen to every conversation, which could lead to a loss of interest or

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motivation for learning. One participant in the in-person group said as follows:

> *I mean, I think sometimes it might have been that people were really passionate about maybe a certain area that I might not have as much interest in, so you would need to certainly wait.* [Interviewee 7]

Theme 2: A Familiar Learning Environment May Facilitate Learning

Some participants felt that they learned better when the learning environment was comfortable. Some participants in the in-person group said that they liked in-person learning because they were *familiar* with its environment. They described in-person learning as *old school* learning where their instructor was physically in front of them. Some said that the in-person workshop was a familiar learning environment, consistent with how they had studied in the past. Thus, for some learners, the familiar learning environment allowed them to easily engage in their learning because that was how they had always learned. Two participants in the in-person group expressed this by saying as follows:

> *I think it is the familiarity and how I am used to learning because with that I can adapt.* [Interviewee 3]
>
> *Oh, I learn better if the person is actually in front of me.* [Interviewee 5]

Often with in-person learning, learners are provided with printed materials. During our in-person DLW workshop, we also provided a printed workbook, and this paper-based material seemed to allow learners to better focus on their learning. One participant in the in-person workshop said as follows:

> *Having paper-based materials typically right in front of me as well is helpful. That is how I typically retain information better. This brain of mine functions better.* [Interviewee 9]

An electronic version of the workbook was provided to participants in the web-based workshop. One participant in the web-based workshop felt less familiar with the web-based learning environment and used her own learning strategy to overcome the challenges she experienced. The participant mentioned that it was not easy for her to go back and forth between the webpages to find an appropriate reference to answer the discussion questions. Thus, she used her own notes and wrote down the key point of the lecture, which she used to answer the discussion questions. In this way, she made the web-based context more familiar to her own learning style to enhance her engagement with the material. She said the following:

> *I do like the website format and kind of like typing out responses, but a downside to that is that I kind of always had to reference material from different pages to look at my answers again. What I found helpful is just like I just kind of write my own notes on the side and I refer to that when I write the answers.* [Interviewee 13]

Theme 3: Synchronous Interaction Is Valuable in the Learning Process

Participants in both the web-based and in-person workshops found synchronous interaction to be a great facilitator of their learning. They mentioned that *nonverbal communication cues* were important in their learning. One participant said as follows:

> *I feel like the in-person, the face-to-face interactions would allow me to take in cues that you may not necessarily be able to get when you are doing even the phone call or teleconference. I truly believe that there is a lot of information in nonverbal communication.* [Interviewee 8]

In addition, *dynamic discussions* seemed to be another important aspect of learning, whereby learners actively exchanged opinions with peers and instructors on various topics regarding the DLW framework. This active process of sharing thoughts exposed them to different perspectives that they had not previously encountered. One participant shared her thoughts regarding dynamic discussions:

> *I think that for me it is the discussions, from hearing others' point of view, and then how other people apply it to situations that I might not even have thought of.* [Interviewee 3]

In contrast, one participant in the web-based group said that there was no opportunity for dynamic discussions in web-based learning:

> *[In online learning] you cannot build as much on top of other people's things. So, you get to see more of what people are saying, but you cannot brainstorm together.* [Interviewee 14]

Furthermore, being able to *ask questions* the moment they had them was another facilitator in the participants' learning. If learners had questions about the content, the learners in the in-person group could immediately ask the instructor. However, unlike the in-person learning environment, it was not easy to ask a question in real time through the web-based learning platform. One participant in the web-based group said as follows:

> *Because it [online learning] was offered asynchronously you did not necessarily have a chance to ask a question at the moment if there was a question.* [Interviewee 15]

Similarly, participants liked to receive *immediate feedback* from peers or instructors during their learning. One participant in the in-person group said:

> *I really liked to have immediate feedback from not just the peers but also the organizers of the workshop.* [Interviewee 8]

Finally, the learners in the in-person workshop liked to *meet other OTs* from different practice settings. One participant in the in-person group said as follows:

> *I really enjoyed meeting other people in that course and seeing what they are doing in their practice. I think a lot of them had a unique OT role and also,*

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> *how they are using the Do-Live-Well method.* [Interviewee 5]

In contrast, one participant in the web-based group expressed that the web-based workshop did not provide the same quality networking opportunities as the in-person workshop:

> *The disadvantage [of online learning] is that you do not necessarily get that face-to-face networking quality.* [Interviewee 18]

Theme 4: Ease of Access to Learning Should Be Considered

Accessibility to learning seemed to be an important aspect that educators should consider when providing educational opportunities. The participants in both the web-based and in-person workshop groups identified some benefits and challenges of accessing each learning format.

First, the participants in the in-person workshop group mentioned that *commuting* was a challenge in accessing the workshop location. For learners who did not have cars, commuting to the workshop location was difficult. In addition, the cold winter weather in Canada affected their access to learning. Two participants in the in-person group commented the following:

> *The challenge is the commute time. Driving there, at the parking, getting the day off work to do it.* [Interviewee 1]

> *I think the weather was not that nice. It was cold. I mean the commute was not that bad from Toronto to Hamilton but obviously, that would have deterred quite a few people if they do not have a car or it is too far to be able to access.* [Interviewee 5]

Some participants in the web-based workshop group mentioned that the web-based workshop was a *safe way* of learning. Owing to the COVID-19 pandemic, web-based education has been considered a safe and primary route by which learners can take courses without worrying about risks. One participant in the web-based group said:

> *I think benefits of online is that, like especially in this COVID season, you can be safe and like kind of not be at risk of being exposed to COVID for sure.* [Interviewee 13]

In addition, learners in the web-based group said that a benefit of web-based learning was that it was *free from geographical restrictions*. Some learners took the web-based courses in Alberta and even while traveling outside of Canada; thus, learners took courses wherever they had internet access, which made learning more accessible for them. One participant in the web-based group expressed as follows:

> *I am in Kingston...being able to take it here and in Argentina, that was beneficial.* [Interviewee 14]

However, if the learner did not have the necessary *equipment* to take the web-based class, such as internet access and a computer, there were restrictions on taking the course itself, which affected learning. Regarding this equipment requirement and its inherent challenges, a participant in the web-based group said: "It was finding a computer that I can use because I do not have my own computer" [Interviewee 10].

Theme 5: Flexibility in Web-Based Learning Can Be Both Beneficial and Challenging

According to the opinions of the participants in the web-based workshop group, the flexibility of web-based learning seemed to be both an advantage and a disadvantage. First, *self-paced* learning was found to be a facilitator of their learning process. In web-based learning, learners could choose the best time of the day to take the course, which possibly decreased potential distractions. Moreover, learners were able to control the speed of learning based on their individual learning styles. A participant in the web-based group shared her thoughts:

> *I would say that you can do it at your own pace. So if you have a setting like I do, where you can have interruptions, you think you might have a certain amount of time to set aside, but you then are interrupted with something that you would like to do or it needs to be done, that you can go ahead and do that, and then you can continue your learning.* [Interviewee 10]

Another benefit of web-based learning was *repeatability*. In web-based learning, learners could repeat the course whenever they wanted. For example, they could repeat the specific content that they did not understand well, and this ability to repeat the course helped learners better understand and remember the content. One participant in the web-based group shared her experience of being able to repeat the content:

> *I liked that I could actually review the videos. I went back to watch them a few times to remind myself what you think. I think I actually went back with one of the later parts of it and went back and watched it again one of the earlier ones. I like that aspect to which I do not think you could do in an in-person setting. You would have to just remember what was happening.* [Interviewee 16]

However, the flexibility of learning also hindered the learning process because some learners *procrastinated* on completing the course. The learners postponed taking the web-based course for various reasons. One participant in the web-based group said:

> *I think I procrastinate. I think it is easier to not set a time to do it. Whereas if it is in-person you are just there. You do not have an option. Okay, you go. For the most part or that is the only time they are offering it. So that is the time you have to get up.* [Interviewee 14]

Some participants also had difficulty *prioritizing* taking the web-based course over other tasks, which affected their overall engagement in learning. A participant in the web-based group expressed the difficulty of prioritizing as follows:

> *So, for me, making it a priority was a bit of a challenge, because I had the flexibility to do it whenever, I did end up doing most of it like the night before it closed. So that was not necessarily how I*

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had anticipated being able to use it. Because of that, my participation in the online forums was pretty minimal. [Interviewee 12]

Discussion

Principal Findings

Considering the appeal and current popularity of web-based learning, we examined the effectiveness of a web-based PBL-based DLW workshop compared with a PBL-based in-person DLW workshop. We also gained insights into learners' perspectives on their participation in both learning formats. The quantitative data showed no statistically significant difference between the groups in knowledge change at the 3 time points (pre-, post-, and follow-up testing), but there was a reduction in knowledge over time in the web-based group. A statistically significant difference was present in factors influencing DLW adoption and satisfaction with the workshop at posttest. However, there was also no difference in the use of the DLW framework 3 months after the workshops. We also identified the key aspects of the learning experience of the participants through our qualitative data: relevance to practice and interest, a familiar learning environment, synchronous in-person interaction, ease of access to learning, and flexibility in web-based learning.

Similar to a recent review of the effectiveness of web-based learning compared with traditional in-person learning for health care professionals [17], the quantitative results about knowledge change showed no differences in knowledge gained between the groups [17]. This suggests that web-based learning is as promising as traditional learning for obtaining knowledge. Undoubtedly, acquiring knowledge is important for health care professionals, as they need foundational knowledge to solve various clinical problems in practice [31]. The participants in our study who attended the in-person workshop had a more satisfying learning experience in all aspects of the workshop based on our quantitative results. Bray et al [32] identified that learners considered interaction as an important factor that led to learning satisfaction. This is reinforced by our qualitative findings, in which participants highlighted the importance of interaction with instructors and peers in the learning process. There were no synchronous interactions in the web-based workshop in our study; thus, as shown by our satisfaction results, the participants in the web-based groups who felt the lack of personal interactions might have been less satisfied with the workshop. In addition, this aspect of social interaction may influence the long-term effect of knowledge retention. This study reported a reduction in knowledge in the web-based group over time, albeit not statistically significant. Real-time social interactions have reported the effectiveness of learning by helping learners "organize their thoughts, reflect on their understanding, and find gaps in their reasoning" [33]. Thus, a lack of synchronous interactions with peers and instructors may negatively impact the knowledge retention and satisfaction of the learners in the web-based group.

Regarding the factors influencing the DLW concepts in practice, immediately after the workshop, the participants in the in-person workshop seemed to be more positive toward the DLW application in their practice; however, 3 months after the workshop, there was no statistically significant difference in the factors influencing DLW adoption between the groups. At the time of the research, the COVID-19 pandemic resulted in significant disruptions in the practice contexts of the OTs, and learners' perceptions of the DLW application might have been affected by the COVID-19 pandemic. The participants who believed that the DLW could be incorporated into their practice faced barriers to its use during COVID-19 pandemic restrictions and changes to their practice. Many in-person programs were canceled, and OTs were busy dealing with urgent situations and changed policies, which may have resulted in decisions not to implement DLW concepts as planned.

Immediately after the DLW workshops, there was the largest difference between the 2 groups regarding the question about how well the participants knew the DLW experts. Compared with the in-person workshop, where the participants could meet and talk with the DLW experts, the participants in the web-based group may have given this question a lower score because they did not have the same opportunity to meet the experts in person. However, this difference between the 2 groups did not last 3 months after the workshops, as indicated by the decreased score in the in-person group. Only 1 person from the web-based group contacted the DLW team after the workshop, and it is expected that even though the participants in the in-person group believed they knew the DLW experts well immediately after the workshop, this impression did not last for 3 months because they did not maintain connections with the experts after the workshop. A recent survey study of the preferences of OTs in continuing education shows that OTs want to receive ongoing individual support even after their education has ended [34]. Thus, we recommend that educators provide a way for learners to stay connected with experts in new knowledge even after disseminating the knowledge. A possible way to connect learners and experts is mentorship. Mentor-mentee programs have been used in occupational therapy education to support the growth of less experienced OTs in professional skills [35,36]. A case study reported that a novice OT found mentorship helpful in applying knowledge to real-world practice, leading to the professional growth of the OT [36]. Thus, having a regular meeting or follow-up check-in opportunity may allow learners to feel connected to the DLW experts, enabling them to sustain their knowledge and support them in applying what they have learned.

The relevance of knowledge to clinical practice and interest was emphasized in our qualitative findings. Regardless of the type of workshop learners participated in, quantitative and qualitative findings suggest that being able to choose a case scenario related to their practice and interest was helpful in their learning process. In a review of learning theories and education for health care professionals, Abela argues that the relevance of new knowledge to learners' clinical practice should be considered when educators decide on discussion topics [37]. Furthermore, Gewurtz et al [38] also noted that PBL is premised on the assumption that "learning is most effective when it is applicable to practice" [38]. Therefore, educators planning to develop web-based and in-person learning for OTs should reflect on how new knowledge is relevant to the learners' practice.

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Our quantitative results revealed that in-person learners appreciated the various elements of the satisfaction questionnaire more positively. This may be the result of the learning preferences of the participants before attending the workshops; both the in-person and web-based groups preferred in-person learning at the pretest. Web-based learners who preferred the in-person learning format may have been less satisfied with the web-based learning format.

In the satisfaction questionnaire, the accessibility of web-based learning was the component with which web-based learners were most satisfied. In the literature, accessibility has been recognized as a great benefit of web-based learning by allowing anyone to access learning materials without restrictions [39]. This benefit of accessibility was made more evident by our qualitative findings. The web-based workshop participants appreciated that they could participate in learning without regional restrictions. Even when traveling abroad during the study period, a participant could take the web-based DLW courses. The benefit of this accessibility would make learning easier for international learners or learners in remote areas who want to learn more about the DLW framework. Therefore, web-based education will help educational institutions or associations that want to attract global learners. Access to reliable internet and web-based learning equipment is important for web-based learning [40]. Since the COVID-19 outbreak, many people have been working from home or taking web-based courses. If a person does not have their own computer and instead shares one with other family members, they may need to wait until the other family members finish using the computer, which may prevent a person from accessing the web-based courses. Thus, access to internet and web-based learning equipment should be considered for web-based learners.

The learners in the web-based group valued the flexibility provided by web-based learning, given that they could take and repeat the modules whenever they wanted because the workshop materials were provided asynchronously. The benefits of the asynchronous feature of web-based learning were that it supported different learning styles and preferences [41]. However, web-based learners stated that the flexibility of web-based learning also hindered their learning. Participants in the web-based workshop found it difficult to prioritize web-based learning over other tasks. Adult learners have responsibilities at home and at work, and they are often placed in a variety of situations that impede learning [42]. Thus, the flexibility of web-based learning seemed to allow learners to prioritize other tasks over web-based courses, resulting in them not having enough time to take the courses. In both the post-and follow-up evaluations, 7 people did not complete the evaluations. Although it was not known whether the participants who did not complete the evaluations completed the web-based courses, the dropout rate in the web-based group may indicate that the flexibility of the web-based learning environment could negatively affect the completion of web-based courses. Moreover, web-based learners in this study seemed to procrastinate in the web-based course; learners' procrastination has been a major disadvantage of web-based learning [43] and it has a negative effect on learners' perceptions of the effectiveness of web-based learning [44].

In our qualitative findings, the lack of ease in networking with others was identified as a challenge of web-based learning. New knowledge is disseminated through communication channels within a social system [26], and educators would need to think of providing the best way to enable learners to communicate with educators and their peers. In our study, although we provided an internet-based space for web-based learners to communicate with each other, the quality of asynchronous communication may be different from that of synchronous communication. The importance of synchronous interactions was emphasized through the interviews with participants in both the web-based and in-person workshops. Thus, adding synchronous communication to web-based learning may benefit learners by encouraging them to engage in their learning more actively. In the literature, an opportunity to have synchronous communication allowed learners to discuss the content in-depth and kept them feeling an urgency for learning [45] and, therefore, may contribute to the successful completion of web-based courses. Furthermore, synchronous communication is more related to the social aspect of learning than asynchronous communication [46]. Considering that OTs value the social aspect of learning [16], future research on continuing education for OTs should include synchronous discussions via video conferences or live chats to maximize benefits. By doing so, learners may have more time to absorb and reflect on what they have learned and to enhance and validate their understanding by asking questions and receiving immediate feedback.

Strengths

To our knowledge, no studies have examined the effectiveness of web-based continuing learning with a comparison group of in-person learners specifically for OTs. This study provided quantitative findings, and the authors were able to directly hear the perspectives and learning experiences of the participants in both web-based and in-person learning environments. We believe this study can support occupational therapy educators in developing and providing effective web-based education by understanding the advantages and disadvantages of the 2 different educational methods.

Limitations

The web-based workshop platform allowed us to identify which participants joined the discussion forums and to see their login information via the workshop website, but we did not know if the participants completed all the course materials. Although we assumed that those who did not complete the postevaluation might not have completed the web-based course, postworkshop evaluation is not an accurate indicator of successful completion of the course. Thus, for future educational studies examining the effectiveness of web-based education, researchers should track learners' course completion, if possible. Unless preinstalled software to track learners' completion is available, researchers may need to ask the participants directly about course completion. In addition, all questionnaires used to measure the outcomes of this study were developed specifically for this study, and thus the reliability and validity of the questionnaires themselves have not been demonstrated. Future studies could focus on developing standard measures to evaluate the effectiveness of educational interventions. In addition, this study

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was conducted in Hamilton, Canada, but participants were recruited from across Canada. We were not able to randomize the participants because OTs far from the study site could not be included in the in-person group. Future studies may consider offering both web-based and in-person workshops to all participants and then randomize them.

Conclusions

This study suggests that web-based education can be effective for OTs, as web-based education enables learners to acquire a similar level of knowledge compared with in-person education. In addition, each educational method has strengths and barriers identified by the learners. Adding a synchronous feature and a mentor or individual follow-up to web-based learning may facilitate more active involvement by participants in their learning, resulting in a more positive web-based learning experience.

Conflicts of Interest

None declared.

Multimedia Appendix 1
Prequestionnaire.
[DOCX File , 88 KB - mededu_v8i1e31634_app1.docx]

Multimedia Appendix 2
Postquestionnaire.
[DOCX File , 51 KB - mededu_v8i1e31634_app2.docx]

Multimedia Appendix 3
Follow-up questionnaire.
[DOCX File , 46 KB - mededu_v8i1e31634_app3.docx]

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Abbreviations

DLW: Do-Live-Well
OT: occupational therapist
PBL: problem-based learning

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Original Paper

Social Determinants of Health Screening by Preclinical Medical Students During the COVID-19 Pandemic: Service-Based Learning Case Study

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Abstract

Background: The inclusion of social determinants of health is mandated for undergraduate medical education. However, little is known about how to prepare preclinical students for real-world screening and referrals for addressing social determinants of health.

Objective: This pilot project's objective was to evaluate the feasibility of using a real-world, service-based learning approach for training preclinical students to assess social needs and make relevant referrals via the electronic medical record during the COVID-19 pandemic (May to June 2020).

Methods: This project was designed to address an acute community service need and to teach preclinical, second-year medical student volunteers (n=11) how to assess social needs and make referrals by using the 10-item Social Determinants of Health Screening Questionnaire in the electronic health record (EHR; Epic platform; Epic Systems Corporation). Third-year medical student volunteers (n=3), who had completed 6 clinical rotations, led the 2-hour skills development orientation and were available for ongoing mentoring and peer support. All student-patient communication was conducted by telephone, and bilingual (English and Spanish) students called the patients who preferred to communicate in Spanish. We analyzed EHR data extracted from Epic to evaluate screening and data extracted from REDCap (Research Electronic Data Capture; Vanderbilt University) to evaluate community health workers' notes. We elicited feedback from the participating preclinical students to evaluate the future use of this community-based service learning approach in our preclinical curriculum.

Results: The preclinical students completed 45 screening interviews. Of the 45 screened patients, 20 (44%) screened positive for at least 1 social need. Almost all of these patients (19/20, 95%) were referred to the community health worker. Half (8/16, 50%) of the patients who had consultations with the community health worker were connected with a relevant social service resource. The preclinical students indicated that project participation increased their ability to assess social needs and make needed EHR referrals. Food insecurity was the most common social need.

Conclusions: Practical exposure to social needs assessment has the potential to help preclinical medical students develop the ability to address social concerns prior to entering clinical clerkships in their third year of medical school. The students can also become familiar with the EHR prior to entering third-year clerkships. Physicians, who are aware of social needs and have the electronic medical record tools and staff resources needed to act, can create workflows to make social needs assessments and services integral components of health care. Research studies and quality improvement initiatives need to investigate how to integrate screening for social needs and connecting patients to the appropriate social services into routine primary care procedures.

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(JMIR Med Educ 2022;8(1):e32818) doi:10.2196/32818

KEYWORDS

social determinants of health; service-based learning; telehealth; preclinical education; screening; referral; community health workers; determinant; medical student; case study; service; preparation; pilot; feasibility; training; assessment; needs; electronic health record; questionnaire

Introduction

The social determinants of health focus on "the conditions in which people are born, grow, live, work and age" and include employment, food security, housing security, access to health care, and transportation as potential contributors to poor health outcomes [1]. Health systems are struggling with how to improve health equity and train care providers to assess social determinants of health and make appropriate referrals in clinical practice [2-10]. The need for social determinants of health screening increased dramatically with the advent of the COVID-19 pandemic in 2020 [11-15]. As stay-at-home orders were instituted, the unemployment rate rose to 20.4% in the New York epicenter by June 2020 [15].

The impact of COVID-19 on health care and medical student training in the United States was dramatic. Health care providers were transferred from outpatient care to inpatient care to manage the influx of gravely ill patients with COVID-19. The Association of American Medical Colleges (AAMC) recommended that medical students be removed from all in-person clinical activities [14]. This left medical students with time for pursuing learning opportunities that do not involve in-person clinical activities.

The AAMC has stressed the importance of service orientation as a core competency that strengthens medical school and residency applications. Community-based service learning activities can facilitate the development of competencies, such as cultural competence and teamwork as well as service orientation, that are needed to improve health equity. The AAMC website suggests that both undergraduate and graduate medical education programs are looking for applicants who "demonstrate a desire to help others and sensitivity to others' needs and feelings; demonstrate a desire to alleviate others' distress; [and] recognize and act on [their] responsibilities to society; locally, nationally, and globally" [16]. The motivation to become a physician frequently comes from a desire to help people. Taking a service year prior to medical school is recommended by the AAMC as a way to make a positive impact on people though work. AAMC-suggested activities for a gap service year have included tutoring children, caring for older adults, supporting veterans, aiding people who are homeless, or helping communities recover from natural disasters. These AAMC-suggested community-based service learning activities generally involve in-person contact. The AAMC did not issue guidance for alternative service activities for medical students, who suddenly had gap time after being removed from in-person clinical activities. However, telehealth can provide opportunities for students to participate in community-based service learning that does not involve in-person clinical activities.

This case study describes the telehealth activities of medical student volunteers who used a social needs screening questionnaire and community health worker referrals to provide patient assistance in a primary care practice setting during the height of the COVID-19 pandemic crisis in New York. The objective of our case study was to evaluate the feasibility of using real-world, service-based learning to teach preclinical medical students how to interview patients by telephone, assess social needs, make appropriate referrals, and enter relevant information into patients' electronic health records (EHRs).

Methods

Setting

This case study describes our work with a primary care practice that provides safety net services as a federally qualified health center and serves as a teaching site within a large urban health system. This health center provides clinical services related to family medicine, internal medicine, pediatrics, obstetrics and gynecology, psychiatry, mental health, and social services and has primary care teams that include community health workers [17]. These services are included as part of the clinical rotations for medical students, and this health center is 1 of the 20 primary care practice teaching sites located in the Bronx and Westchester County, New York.

Patient Population

The medical director identified patients (n=53) for social determinants of health telephone screening based on the following criteria: patients aged ≥50 years, those who were due for colorectal cancer screening (via colonoscopy), and those who did not have insurance. Due to the acuity of the pandemic crisis and the need to screen and intervene on the needs of a large patient population, the contact list provided was based on readily available clinic data (eg, patients due for colonoscopy), and the medical director focused on patients without health insurance for outreach purposes.

Role of Medical Student Volunteers

Preclinical, second-year medical student volunteers (n=11) were recruited via email. Third-year medical student volunteers (n=3), who had completed 6 clinical rotations, developed and led a 2-hour skills development training workshop for the preclinical second-year students. The workshop PowerPoint slides are in Multimedia Appendix 1. The learning objectives included being able to (1) navigate the Epic platform (Epic Systems Corporation) EHR, (2) screen for social needs, and (3) refer patients to the appropriate care providers. If potential domestic violence was a concern for a patient, they were referred to a social worker; patients with other social needs were referred to the community health worker. The training addressed how to sensitively approach patients about social needs screening. The

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third-year medical students provided ongoing mentoring, peer support, and guidance (ie, they answered questions) for contacting patients via telephone, conducting patient interviews, and documenting the Social Determinants of Health Screening Questionnaire assessments and related referrals via the Epic portal.

Preclinical Training: Social Determinants of Health and Community-Based Service Learning

Preclinical medical students have varying degrees of exposure to opportunities for learning about social determinants of health–related topics and developing skills for addressing socially determined health disparities. Exposure is provided via the medical school curriculum, and skills can be acquired by volunteering in community-based service learning projects. Embedded in the first 2 years of the medical school curriculum is the *Introduction to Clinical Medicine* longitudinal course. The topics addressed in this course include patient health literacy, HIV, social determinants of health, and substance abuse. Interviewing skills for obtaining a sexual history are taught via practice mock interviews with standardized patients. The medical school volunteer opportunities are available through the *Community-Based Service Learning* program, which is comprised of a network of student-initiated projects, including the sponsoring of a community garden and a wide variety of community education projects. Students also have the option of volunteering at the Einstein Community Health Outreach clinic, which is a largely medical student–run free clinic that aims to provide quality care to uninsured patients. Preclinical medical student volunteers at the Einstein Community Health Outreach clinic serve a variety of roles that frequently involve screening for social needs.

The 10-Item Social Determinants of Health Screening Questionnaire and Referral Procedures

In 2017, a multidisciplinary committee within the health system used the suggested procedures from the Health Leads Social Needs Screening Toolkit [18] to develop a 10-item Social Determinants of Health Screening Questionnaire (Table 1). Clinically validated question items from the toolkit's screening library were chosen to assess the essential social needs domains (housing instability, utility strain, food insecurity, transportation, financial resources strain, and exposure to violence) and 2 optional social needs domains (childcare and behavioral and mental health). The questionnaire's reading level was slightly below the sixth-grade reading level (Flesch-Kincaid grade level of 5.9); Microsoft Word Editor was used to calculate readability statistics [19]. To accommodate the language diversity within the health system, the questionnaire was translated into 9 languages.

Table 1. Social Determinants of Health Screening Questionnaire.

Screening questions with "yes/no" response options	Social needs domain
Question 1: "Are you worried that in the next two months you might not have a safe place to live? (eviction, kicked out homelessness)"	Housing instability[a]
Question 2: "Are you worried that the place you are living now is making you sick? (has mold, bugs, rodents, water leaks, not enough heat)"	Housing quality[b]
Question 3: "In the last 3 months, has the electric, gas, oil or water company threatened to shut off services to your home?"	Utility strain[a]
Question 4: "In the last 12 months, did you worry that your food could run out before got money to buy more?"	Food insecurity[a]
Question 5: "In the last 3 months, has lack of transportation kept you from medical appointments or getting your medication?"	Transportation[a]
Question 6: "In the last 3 months, did you skip buying medication or going to the doctor's appointment to save money?"	Financial resources strain[a]
Question 7: "Do you need help getting childcare or care for an elderly or sick adult?"	Childcare[c]
Question 8: "Do you need legal help? (child family services, immigrations, housing, discrimination, domestic issues, etc.)"	Legal[b]
Question 9: "Are you finding it so hard to get along with a partner, spouse, or family member that it is causing you stress?"	Behavioral and mental health[c]
Question 10: "Does anyone in your like hurt you, threaten you, frighten you or make you feel unsafe?"	Exposure to violence[a]

[a]This domain is identified as an essential social needs domain in the Health Leads Toolkit [18].

[b]This domain is identified as an important social needs issue by the multidisciplinary committee of the health system.

[c]This domain is identified as an optional social needs domain in the Health Leads Toolkit [18].

The 10-item Social Determinants of Health Screening Questionnaire was integrated into the EHR across the entire health system in 2018. The health system uses paid, trained, and supervised community members to provide health education and coaching, assistance with clinical services, and community resource connections [20]. However, practice sites within the system determine their own procedures for using the EHR Social Determinants of Health Screening Questionnaire and criteria for community health worker referrals. The practice site that participated in this pilot project had not incorporated a systematic procedure for administering the Social Determinants

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of Health Screening Questionnaire during clinical procedures by the onset of the COVID-19 pandemic in early 2020.

Plan-Do-Study-Act Framework

The Plan-Do-Study-Act framework [6] was used to inform how we developed and evaluated the project, which was designed to help the practice site with social needs screening and to provide real-world, service-based learning for preclinical medical student volunteers during the COVID-19 shutdown. Our process steps are outlined below.

Plan

Third-year medical students collaborated with the medical director, social worker, and community health worker from the clinical site to develop the project procedures and training program. The planning process addressed procedures for conducting the telephone interviews, entering patient responses into the EHR, and referring patients with social needs to the social worker and community health worker.

Do

Preclinical, second-year medical student volunteers were recruited by email. They participated in a 2-hour skills development orientation that taught them how to navigate the Epic platform EHR, screen for social needs, refer patients with social needs, and approach sensitive topics empathetically. The third-year medical students provided ongoing mentoring, peer support, and guidance (ie, they answered questions) for contacting patients via telephone and conducting patient interviews. The preclinical students conducted 47 social needs screening phone interviews and referred 20 patients.

Study

We evaluated screening outcomes by using the data extracted from the patients' EHRs as well as project-specific data. Students' feedback was obtained to evaluate the pilot project and to elicit recommendations for using service-based learning as a modality for increasing preclinical students' knowledge and skills related to social determinants of health.

Act and Adjust

The lessons learned from this pilot project are being used to inform curriculum planning for preclinical courses that address social determinants of health. The project findings provide insights for future quality improvement initiatives and research that focuses on social needs within the context of health care.

Social Determinants of Health Screening Telephone Calls

Social determinants of health screening was performed by the preclinical medical students via telephone; the calls were conducted in patients' preferred language (English or Spanish). Bilingual students called patients who preferred to communicate in Spanish. Our feasibility case study focused on screening calls conducted during May and June 2020. All calls were made by using clinic-approved cellphone apps (eg, Doximity [Doximity Inc]) affiliated with the clinic's telephone number. Patients responded to the ten social risk questions by answering "yes" or "no" to each of the items in the screener. Patients who answered "yes" to any item were referred to an appropriate care provider. Referrals were made to a trained and supervised community health worker, who was an embedded staff member of the participating practice site. The site's community health worker linked patients and their households to the appropriate community, state, and federal resources. For patients who preferred to communicate in Spanish, the community health worker, who was not bilingual, used a telephone translation service. Any patient who expressed any safety concerns (eg, domestic violence) or exhibited relationship stress was referred directly to a social worker for assistance and was not included in the analysis.

Data Extraction and Institutional Review Board Approval

For this project, the social determinants of health screening data were extracted by an analytics team and provided to administrative and medical directors within the ambulatory network for quality improvement investigation–related activities. These data included patients' responses to the Social Determinants of Health Screening Questionnaire; dates of visit encounters; and patients' medical record numbers, which facilitated linkages to other databases. This project was reviewed and approved by the Montefiore-Einstein Institutional Review Board (approval number: 2017-8434).

Primary Outcomes and Covariates

The primary outcomes for this project were the number of screenings completed and referral status (ie, patients' uptake of social services that were recommended by the community health worker). Completed screenings were defined as screenings in which patients answered all 10 questions. Community health worker referrals were categorized as either successful or unsuccessful. A referral was successful if the community health worker helped a patient access at least 1 resource related to a screened social need. If a patient had self-identified social needs but the community health worker encounter did not facilitate access to relevant resources, the referral was categorized as an unsuccessful referral. Independent covariates were extracted from the REDCap (Research Electronic Data Capture; Vanderbilt University) database [21] based on patients' self-reports and included sex; age; race and ethnicity; preferred spoken language; and social need categories, including housing needs, benefit needs, youth and family service needs, legal needs, and "other" needs. Comments in REDCap were used to describe needs in the "other" category. These needs were not specific, and these comments included the term *social need* or *community resource*.

Results

Questionnaire and Demographic Data

Questionnaire and demographic data were retrieved via Epic. Hispanic and non-Hispanic Black patients constituted the majority of patients (37/45, 82%). Of the 45 patients who had screening data, 20 had at least 1 social need. Almost all of the patients with a social need (19/20, 95%) were referred to the community health worker, who reached most of them (16/19, 84%) to provide a social needs consultation between May and October 2020. Table 2 summarizes the demographic

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characteristics and outcomes of all patients who completed screening. Patients who were successful in obtaining social needs resources tended to be older than those who were unsuccessful. Spanish-speaking patients constituted 38% (3/8) of the patients who were unsuccessful in obtaining social needs resources.

As shown in Table 3, the majority of patients (13/16, 81%) had 1 social need identified. The most common social need was food insecurity, which was reported by half (8/16, 50%) of the patients who had consultations with the community health worker and was irrespective of whether the referral was successful.

Table 2. Social determinants of health screening, community health worker referrals, and success in obtaining needed social service resources.

Patient characteristics	Completed screening (n=45)	No social needs identified (not referred; n=25)[a]	Community health worker referral consultations (n=16)[b,c]	
			Successful in obtaining social service resources (n=8)	Unsuccessful in obtaining social service resources (n=8)
Age (years), mean (SD)	60 (5.7)	60 (5.1)	58 (6.5)	54.5 (6.6)
Sex, n (%)				
Male	19 (42)	13 (52)	2 (25)	1 (13)
Female	26 (58)	12 (48)	6 (75)	7 (88)
Race and ethnicity, n (%)				
Hispanic	21 (47)	8 (32)	5 (63)	6 (75)
Non-Hispanic Black	16 (36)	12 (48)	1 (3)	2 (25)
Non-Hispanic White	2 (4)	1 (4)	1 (3)	0 (0)
Non-Hispanic	1 (2)	0 (0)	1 (3)	0 (0)
Asian or Pacific Islander	1 (2)	1 (4)	0 (0)	0 (0)
Other or unknown	4 (9)	3 (12)	0 (0)	0 (0)
Preferred spoken language, n (%)				
English	34 (69)	21 (84)	4 (50)	5 (62)
Spanish	14 (31)	4 (16)	4 (50)	3 (38)

[a]Patients who responded to all of the social needs questions were not referred to the community health worker.

[b]A total of 3 patients were lost to follow-up or did not report having social needs during the community health worker assessment; therefore, they were not included in the analysis.

[c]One patient expressed concerns regarding personal safety, was referred to the social worker rather than the community health worker, and was excluded from the analysis.

Table 3. Community health worker consultations.

Social needs	Patients who were successful in obtaining social service resources (8/16, 50%), n (%)	Patients who were unsuccessful in obtaining social service resources (8/16, 50%), n (%)
Number of social needs		
1	7 (88)	6 (75)
2	0 (0)	1 (13)
3	1 (13)	1 (13)
Type of social needs		
Food insecurity	4 (50)	4 (50)
Housing[a]	1 (13)	2 (25)
Other needs	4 (50)	5 (63)

[a]This need was related to applying for a bed in a shelter or for public housing.

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Students' Feedback

The second-year preclinical student volunteers indicated that their motivation for participating in this project came from the desire to do something concrete and useful during the COVID-19 pandemic and the recognition of their lack of clinical experience and limited capacity to help in clinical settings. Students' feedback also addressed how the experience helped to expand their clinical skills, as indicated in the following comment:

> *…there is a piece of your education that has to be about how you talk about social determinants of health…but there is another piece where now that you've identified a need, what are you going to do...Those are two different skill sets and I think I got practice with both of those things by doing the calls.*

The preclinical student volunteers supported adding more service-based initiatives and more formal social determinants of health training to the curriculum. One comment focused on how aspects of their medical education were both similar to and different from their real-world project experience, as follows:

> *We do a lot of talking [in medical school] about what are the social determinants of health…but there are gaps in understanding what the particular needs are in a particular community and talking to patients about them, which can be really tough. It is kind of like taking a sexual history. The first time you do it, it feels very awkward and invasive…you really have to do it multiple times to learn how to do it well…often maybe we are doing it [asking social needs questions] for the first time as third years….*

Discussion

Main Results

The preclinical medical student volunteers indicated that participating in this service-based learning project increased their ability to assess social needs and make social service referrals by using the EHR 10-item Social Determinants of Health Screening Questionnaire. Of the patients with a social need, 80% (16/20) had a consultation with the community health worker, and half of these patients (8/16, 50%) were connected to at least 1 resource to address their social needs. About one-third (14/45, 31%) of the total patients who were screened preferred to speak Spanish, but Spanish-speaking patients constituted 38% (3/8) of the patients who were unsuccessful in obtaining social needs resources after their community health worker consultation. All of the community health worker consultations with patients who preferred to communicate in Spanish were conducted via a translation service because the community health worker was not a Spanish speaker.

Comparison With Prior Work

Fiori et al [2,3] used a similar social determinants of health survey and reported a successful social service uptake (ie, social services recommended by the community health worker) rate of 43%; the screening surveys were completed in the waiting rooms of a pediatric ambulatory clinic, and the primary care physician reviewed the surveys with the patients. Although addressing the five major social determinants of health (food security, housing access, transportation issues, utility needs, and interpersonal violence) can improve patient outcomes, a 2019 paper by Fraze et al [4] reported that only about 16% of physician practices in the United States screen for all 5 domains. Medical training needs to address how to integrate an empathic discussion of social needs as a standard of care. Taking a sexual history in an inoffensive way is generally taught via practice interviews with standardized patients, and this approach may be applicable to assessing the social determinants of health. Didactics and service activities may facilitate the teaching of needed skills. Screening for determinants of health can be incorporated into community-based service learning programs.

The feedback from the student volunteers suggests that undergoing preparatory training, administering the survey, and making community health worker referrals were valued as service-based learning experiences in health disparity intervention. The evaluation of medical students' learning experiences can provide insights for skills training in undergraduate medical education. Medical students who learn about the social determinants of health through service and formal curricula have been explored in the literature [22,23]. The Health Scholars Program was an immersive 9-month pilot curriculum on the social determinants of health in which medical students and other types of health professional students in Pennsylvania learned through community service, didactics, and critical reflection [20]. Additionally, medical students at the Morehouse School of Medicine in Atlanta, Georgia, participated in a medical-legal, 4-session curriculum that aimed to teach students how to collaborate in medical-legal partnerships to identify and address the social needs of patients in their communities [21]. In both cases, there was a significant pre-post increase in medical students' desire to screen for social needs [22,23]. There is growing evidence that providing undergraduate medical students with tools for screening and tracking social determinants of health via the EHR acculturates them to the importance of addressing social determinants of health to reduce health disparities [9]. Individual- and community-level social determinants (ie, those tracked in the EHR) have been proposed as vital signs [24]. The EHR infrastructure and a trained and motivated workforce provide the foundation needed to adequately address social needs and reduce health disparities.

Limitations

There are several limitations to this case study. First, the Plan-Do-Study-Act cycle focused on immediate needs and did not address how to integrate social determinants of health screening into the clinical routine. Second, the patient sample size was too small for statistical comparisons. Third, success was defined as a patient being connected with at least 1 social needs resource; therefore, if a patient had more than 1 social need and only 1 was addressed, their encounter was deemed successful, even if their needs were only partially addressed. Fourth, medical students entered social needs screening information into the EHR, and referral data were recorded in REDCap. As such, errors and misclassification bias are possible. Further, some patients may have underreported social needs due to perceived stigma, the sensitive nature of certain topics,

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or disclosure concerns, thus raising the possibility of self-report bias. Fifth, the community health worker and some of the medical students involved in this study were not Spanish speakers and needed to use a phone interpreter to interact with Spanish-speaking patients, which could have affected rapport building and the exchange of information. Sixth, the student volunteers represented a little over 5% (11/180, 6.1%) of the average number of enrolled students, and methods for increasing the proportion of medical students who participate in service-based learning for social needs assessment should be considered. Finally, our qualitative data were limited to informal feedback from the medical students, and we did not systematically ask the students, patients, or the community health worker to reflect on the process or the lessons learned. Despite these limitations, our findings may provide useful information that can inform the planning of medical education, health system research, and quality improvement initiatives.

Conclusions

The students developed proficiencies in assessing social needs and documenting their assessments and related referrals in the EHR. In this successful service-based learning experience, preclinical medical students learned how to use community health worker referrals to address social needs. The participating students also gained experience in broaching potentially uncomfortable topics, identifying related needs, and performing the appropriate next steps to address these needs. Since the participating second-year medical students were in preclinical training, this volunteer experience may have been their first exposure to an ambulatory setting and social needs assessment. Opportunities for asking patients about their struggles with social needs can provide a meaningful and memorable experience to medical student trainees. Early practical exposure to social needs assessment has the potential to help medical students develop the ability to address social concerns prior to entering clinical clerkships in the third year of medical school. Finally, medical students gained familiarity with the EHR prior to entering third-year clerkships. Integrating social determinants of health into undergraduate medical curricula could increase the awareness of social needs in the physician workforce, and the integration of the 10-item Social Determinants of Health Screening Questionnaire has resulted in a tool for integrating social needs assessment into clinical practice. Physicians, who are aware of social needs and have the electronic medical record tools and staff resources needed to act, can create workflows to make social needs assessment and services integral components of health care. Larger-scale studies need to assess the effect of integrating screening for social needs and connecting patients to the appropriate social services into routine primary care procedures.

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Conflicts of Interest

None declared.

Multimedia Appendix 1
Social determinants of health screening project: preclinical student volunteer training (PowerPoint slides).
[PPTX File , 9985 KB - mededu_v8i1e32818_app1.pptx]

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Abbreviations

AAMC: Association of American Medical Colleges
EHR: electronic health record
REDCap: Research Electronic Data Capture

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Original Paper

Perception of Web-Based Didactic Activities During the COVID-19 Pandemic Among Anesthesia Residents: Pilot Questionnaire Study

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Abstract

Background: Physical and social distancing recommendations aimed at limiting exposure during the COVID-19 pandemic have forced residency programs to increasingly rely on videoconferencing and web-based resources.

Objective: In this pilot study, we aimed to explore the effects of the COVID-19 pandemic on residency training experience, and to delineate the perceived barriers to the successful implementation of web-based medical education.

Methods: A 19-item survey was compiled and distributed electronically using Qualtrics. This anonymous survey included information on the training level of each resident, their participation in formal didactics before and during the pandemic, and their perception of the ease and limitations of virtual didactics. The resident's opinions on specific educational resources were assessed, and the effectiveness of new delivery methods on resident engagement and learning was examined.

Results: Thirty anesthesiology residents were surveyed, 19 of whom agreed to participate in the pilot study. One participant with incomplete responses was excluded, yielding a final cohort of 18 respondents. Most residents (56%, 10/18) reported that the COVID-19 pandemic negatively affected their residency training. The time spent on didactic training and independent studies was, nevertheless, not affected by the pandemic for 90% (16/18) of respondents. Nonetheless, 72% (13/18) of residents were less engaged during virtual lectures in comparison to in-person didactics. Important limitations included distraction from the physical environment (67%, 12/18), internet instability (67%, 12/18), less obligation to participate (44%, 8/18), technical difficulty and unmuted microphones (33%, 6/18, each), and people speaking over each other (28%, 5/18). Despite these limitations, most residents stated that they would like to keep a combination of virtual didactics including live Zoom lectures (56%, 10/18), prerecorded web didactics (56%, 10/18), and virtual ground rounds via Zoom (50%, 9/18) as the "new normal."

Conclusions: Despite important limitations listed in this report, anesthesia residents would like to keep a combination of virtual lectures and presentations as the new normal after the COVID-19 pandemic.

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KEYWORDS

resident education; COVID-19; barriers to education; didactic; medical education; online education; web-based education; virtual training; anesthesiology residents; medical residents; pandemic; virtual didactics

Introduction

Didactic activities are an important component of anesthesia residency training and are required by the Accreditation Council for Graduate Medical Education [1]. As frontline workers were involved in aerosol producing procedures with the highest risk of transmission during the peak of the COVID-19 pandemic in Boston, Massachusetts, anesthesia residents were heavily

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affected by the added stress of potential infection and changing clinical responsibilities, while adapting to a modified didactic curriculum and remote learning [2]. Physical and social distancing recommendations [3] aimed at limiting exposure during the COVID-19 pandemic led to the cancellation of face-to-face didactic activities [4], forcing residency programs to increasingly rely on videoconferencing and web-based resources. While limiting the risk of exposure during a pandemic, virtual meetings and web-based resources allow the residents to work closely with other trainees and faculty within their institution, in addition to breaking geographic restrictions through cost-effective collaborative networks for educators across the nation and beyond [5]. The learning experience may be limited by technical barriers, lack of engagement, distraction from physical environments, and other factors that have yet not been fully explored. Course development and delivery are also critical for success. In a study comparing the differences in virtual versus in-person training for occupational therapists, researchers found that while knowledge acquisition did not differ between the two groups, participant's satisfaction rating was higher for the in-person group than for the web-based group owing to lack of in-person interactions, lack of ease in networking, and synchronous interactions in the web-based setting. The same study also found that participants appreciated the ease of accessibility and flexibility provided by the web-based learning modules [6]. Another study assessing the development of empathy in premedical students found a significant increase after a 2-week remote learning course. However, since comparisons to empathy development in a similar in-person course are missing, it is difficult to determine whether a similar or greater increase in empathy would not have been observed in an in-person setting [7]. The authors could not identify previous studies on the effect of distance learning on significant components of postgraduate medical education such as knowledge acquisition, engagement, and the development of empathy. It is hence unclear whether virtual meetings and didactics can satisfy the educational needs of residents and ensure the quality of experience that is required for their academic, clinical, and professional growth, and further research is needed to address this gap.

In this pilot study, we aimed to explore the effects of the COVID-19 pandemic on the residency training experience and delineate the perceived barriers to the successful implementation of web-based medical education within our anesthesiology residency program, using a self-reported, anonymous survey.

Methods

Ethical Considerations

The institutional review board at the Boston Medical Center determined that this study (H-40592) qualified for an exemption, under the policies and procedures of the Human Research Protection Program.

Study Overview

Boston Medical Center is the largest safety net level 1 trauma center in eastern Massachusetts. Because of the significant impact of the pandemic and large number of patients with COVID-19, all elective surgeries were suspended and residents were deployed to airway and intubation teams, ventilator management teams, critical care and obstetric services, or emergency surgeries. All lectures, grand rounds, case conferences, and morbidity mortality discussions were transitioned to web-based class sessions using a cloud-based teleconferencing software platform (Zoom). On July 24, 2020, after the initial peak in COVID-19 cases at our hospital, we distributed a 19-item survey to all residents in our training program (N=30) using Qualtrics Survey Software [8]. Following the initial survey distribution, 2 weekly electronic reminders were sent to the residents. The survey was closed for responses on August 7, 2020. This anonymous survey included information on the training level of each resident, their participation in formal didactics before and during the pandemic, and their perception on the ease and limitations of virtual didactics. Activities under "formal didactics or independent learning" included lectures and topics on basic and advanced anesthesia such as clinical pharmacology, cardiovascular and respiratory physiology, perioperative medicine, and considerations for complex disease states and surgical procedures. Special topics related to the pandemic such as airway management in patients with suspected or confirmed COVID-19 were, of course, added to the curriculum, but the basics of perioperative medicine and critical care remained unchanged. In addition to these lectures, anesthesia residents also participated in regular Grand Rounds and Case Conferences, discussing topics of interest to the perioperative medicine and special considerations in patients with comorbidities and other perioperative concerns.

The survey was developed by a formative committee within our department using a modified Delphi technique with a three-generation telephone interview, personal interview, and conference [9]. After obtaining ethics approval form the institutional review board, the survey was piloted with 3 academic physicians (experts) and 3 trainees (respondents) in our department, and iteratively revised to improve clarity and construct validity. The context of the survey was determined by its main purpose of examining the effectiveness of virtual teaching to anesthesia residents, taking into consideration the environmental, educational, cultural, and social context of medical education. Close-ended questions were mainly chosen to better standardize, collect, and analyze the data and because of their high reliability, and some open-ended questions were also included to provide freedom of expression and allow for unanticipated responses.

All data are reported as frequencies and percentages. The time spent on formal didactics or independent learning before and during the COVID-19 pandemic were considered ordinal data and compared using the Friedman nonparametric test. Free-text comments were categorized into representative themes and analyzed using conventional qualitative content analysis [10].

Results

We surveyed our anesthesiology residents (N=30), 70% of whom (range 21-30) responded and 63% (N=19) agreed to participate in this pilot study. One participant was excluded owing to incomplete responses, making the final cohort comprise 18 participants (60%). A larger proportion of junior residents

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(clinical anesthesia year 1 or CA-1) responded to the survey (8/18, 44%) compared to the senior residents (5/18, 28%, for CA-2; 5/18, 28%, for CA-3) (Table 1). The response rate was 100% for all questions except for the question of the impact of COVID-19 on residency training, which yielded a 67% response rate (12/18).

Most residents (56%, 10/18) reported that the COVID-19 pandemic negatively affected their residency training. Four residents (22%, 4/18) felt that their training was not affected, and another 22% (4/18) of respondents felt that it was positively affected by the pandemic. Hands-on training in the operating rooms was reported to be reduced for 56% (10/18) of responding residents, a majority of whom (70%, 7/10) reported a >50% reduction.

No significant differences were observed in the time spent on formal didactics (*P*=.50) or independent study (*P*=.70) before and during the COVID-19 pandemic, irrespective of the seniority of the residents. Additionally, a higher proportion of residents reported spending 0-5 hours on didatics during than before the COVID-19 pandemic (61%, 11/18 vs 50%, 9/18, respectively). This change reflects an equal decrease in residents who report spending 5-10 hours on formal didactics before than during the COVID-19 pandemic (44%, 8/18 vs 33%, 6/18, respectively).

Table 1. Distribution of respondents by year in residency training and time spent on didatics before and during the COVID-19 pandemic (N=18).

Time spent on didactics (hours)	Respondents before the COVID-19 pandemic, n (%)	Respondents during the COVID-19 pandemic, n (%)
Clinical anesthesia year 1		
0-5	2 (25)	5 (62.5)
5-10	6 (75)	3 (37.5)
>10	0 (0)	0 (0)
Clinical anesthesia year 2		
0-5	3 (60)	3 (60)
5-10	2 (40)	1 (20)
>10	0 (0)	1 (20)
Clinical anesthesia year 3		
0-5	4 (80)	3 (60)
5-10	0 (0)	2 (40)
>10	1 (20)	0 (0)

In total, 56% (10/18) of residents felt that attending virtual didactics was easy; 39% (7/18) of respondents felt that it was neither easy nor difficult. A majority of residents (72%, 13/18) reported that their engagement during virtual didactics was lower or much lower than that in in-person didactics. Besides question banks, textbooks, web-based videos, and formal didactics were the top 3 resources to enhance residents' clinical performance and help their preparation for standardized assessments (eg, board exams).

As illustrated in Figure 1, barriers to engagement included distraction from the physical environment (67%, 12/18), internet instability (67%, 12/18), less obligation to participate (44%, 8/18), technical difficulty and unmuted microphones (33%, 6/18, each), and people speaking over each other (28%, 5/18). In addition, 72% (13/18) of residents felt that the pandemic negatively affected their interaction with their colleagues. Despite these limitations, most residents stated that they would like to keep a combination of virtual didactics including live Zoom lectures (56%, 10/18), prerecorded web-based didactics (56%, 10/18), and virtual ground rounds via Zoom (50%, 9/18) as the "new normal."

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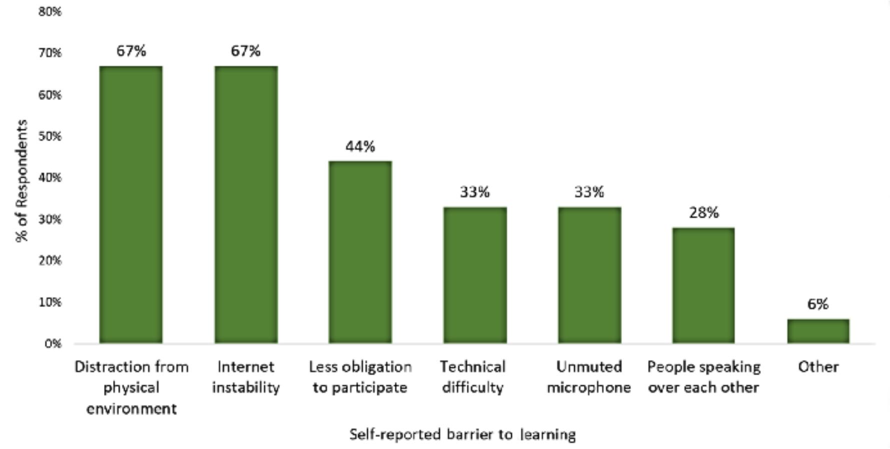
Figure 1. Self-reported barriers to web-based learning using virtual didactics.



Discussion

Principal Findings

The results of this pilot study demonstrate some of the negative impacts of the COVID-19 pandemic on medical education and residency training. Not only did residents report a reduction in hands-on patient care and bedside training in the operating rooms during the pandemic, but they also reported decreased interaction with peer residents, faculty, and other health care providers. Remarkably, the time spent on didactic activities did not change during the surge of the pandemic, and our residents were generally satisfied with their web-based learning opportunities, despite the many limitations associated with virtual lectures, conferences, and grand rounds. This reported comfort and satisfaction with web-based education is consistent with findings from other studies on the effects of the COVID-19 pandemic on medical education [11] and illustrates the ability of both residents and educators to effectively adapt to the significant changes that were brought forth by the COVID-19 pandemic. Although not specifically explored in this survey, these educational innovations included reformatting lectures and conferences to better fit the new web-based forum; recruitment of local, regional, and national speakers; and a focus on active leaning techniques, small group case discussions, and visual diagnostic and panel discussions. Specifically with respect to the field of anesthesiology, virtual didactics may have additional benefits to postcall residents who may not have previously been able to attend didactics in person but can attend virtually. This also applies to intensive care unit residents as well as those on external rotations.

Remote learning can present unique challenges for anesthesia trainees and residents. The videoconferencing software used in our institution (Zoom) allows annotation on a shared screen without interrupting the speaker. However, unintended interruptions from unmuted microphones and other technical difficulties such as internet instability can negatively impact the ability to remain attentive during virtual didactics, as was reported by our residents. Our residents were also distracted owing to physical environments that are inherent to web-based lectures and conferences. Most technical limitations can be addressed by simple modifications or upgrades of the conferencing software. For instance, distractions from unmuted microphones can be eliminated by activating the push-to-talk feature, which requires attendees to hold down a key to be unmuted. Speaking over each other can also be reduced if the speaker controls all microphones and determines when to open the session for questions or discussions. In contrast, environmental and pedagogic challenges may require a more sophisticated and innovative approach [12]. Examples include real-time facilitation by messaging discussion forums, question-and-answer polling, social feeds, and private notes to improve the experience and increase audience engagement. Large-group didactics can be replaced with the more interactive small-group case discussions and question-and-answer platforms.

Despite these software, internet, and environmental improvements, nevertheless, it is difficult to expect the same level of engagement with virtual learning as in-person didactics. Therefore, we expected that a majority of residents would prefer to eliminate virtual didactics after the pandemic and revert to traditional, face-to-face learning. To our surprise, however, a majority of our residents reported that they would like to keep virtual didactics, grand rounds, and web-based video learning as the new standard.

Limitations

While the results of our pilot study provide new insights into the challenges and barriers associated with remote learning specific to anesthesia residents, our study has several limitations. Importantly, use of the survey methodology is associated with inherent limitations such as interpretation bias, social desirability bias, and lack of personalization. Moreover, our small sample is only representative of one academic institution during a surge in COVID-19 cases. The purpose of this study was to examine the effects of the pandemic on residency training experience, and it does not have the power to examine every aspect of web-based education. We did observe an increasing number of regional and national speakers during the completion of the survey and new approaches to improve the technology, but as these innovations and changes were not specifically examined in our study, we are unable to carry out further evaluation. Future studies are needed to address the impact of these innovations on resident education.

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Conclusions

Virtual didactics will certainly not replace bedside training, simulation training, or technical skill teaching, including ultrasound training, line placement, regional anesthesia, and—for all surgical specialties—hands-on surgical skill training. For didactic activities, nevertheless, residency programs may plan and design a hybrid curriculum that includes both in-person and virtual components, even beyond the COVID-19 pandemic. Larger studies are warranted to outline the specific barriers and opportunities for remote learning in different medical specialties. Innovations aimed at improving virtual didactics are also needed, as are studies to evaluate their efficacy and educational values within each medical field.

Conflicts of Interest

None declared.

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Original Paper

Health Care Students' Perspectives on Artificial Intelligence: Countrywide Survey in Canada

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Abstract

Background: Artificial intelligence (AI) is no longer a futuristic concept; it is increasingly being integrated into health care. As studies on attitudes toward AI have primarily focused on physicians, there is a need to assess the perspectives of students across health care disciplines to inform future curriculum development.

Objective: This study aims to explore and identify gaps in the knowledge that Canadian health care students have regarding AI, capture how health care students in different fields differ in their knowledge and perspectives on AI, and present student-identified ways that AI literacy may be incorporated into the health care curriculum.

Methods: The survey was developed from a narrative literature review of topics in attitudinal surveys on AI. The final survey comprised 15 items, including multiple-choice questions, pick-group-rank questions, 11-point Likert scale items, slider scale questions, and narrative questions. We used snowball and convenience sampling methods by distributing an email with a description and a link to the web-based survey to representatives from 18 Canadian schools.

Results: A total of 2167 students across 10 different health professions from 18 universities across Canada responded to the survey. Overall, 78.77% (1707/2167) predicted that AI technology would affect their careers within the coming decade and 74.5% (1595/2167) reported a positive outlook toward the emerging role of AI in their respective fields. Attitudes toward AI varied by discipline. Students, even those opposed to AI, identified the need to incorporate a basic understanding of AI into their curricula.

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Conclusions: We performed a nationwide survey of health care students across 10 different health professions in Canada. The findings would inform student-identified topics within AI and their preferred delivery formats, which would advance education across different health care professions.

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KEYWORDS

medical education; artificial intelligence; allied health education; medical students; health care students; medical curriculum; education

Introduction

Background

Artificial intelligence (AI) is poised to revolutionize modern health care in the near future. Health care provision, as well as the roles of providers, may be affected by AI through enhanced clinical decision-making, streamlined clinical workflow, improved resource allocation, reduced workloads, and improved efficiency [1-5]. The most prominent current applications of AI in the medical field are in medical imaging analysis [3], particularly with the use of deep learning (DL). DL, a subfield of AI, is defined as "a type of artificial intelligence that uses a layered algorithmic architecture to analyze data" [6]. DL has a wide range of applications and is especially useful for identifying complex yet subtle discriminative patterns in images [3]. Such proficiency is applicable in pattern-centric disciplines of medicine, including radiology, dermatology, and pathology [1,2,7]. As AI continues to evolve, its use is expanding beyond image classification to signal processing in cardiology [8,9] and natural language processing in psychiatry [10] and will continue to grow.

A recent surge in interest in training health care students in AI is reflective of the increasing integration of AI applications in education, research, and clinical care. Among others, the Royal College of Physicians and Surgeons of Canada and the Association of American Medical Colleges have recommended education for health care professionals related to AI, including data provenance and curation, ethics of AI, and critical appraisal and interpretation of AI applications in health care [11-14]. In addition, limited AI exposure has been shown to induce anxiety in undergraduate medical students, affecting their future career decision-making [15,16]. Therefore, exploring the general attitudes and current knowledge base of health care students may be a powerful approach for highlighting areas of need for curriculum decision-makers with respect to AI education [17].

Despite the growing role of AI in health care, the literature on the perspectives of health care students on AI is scant. To date, a few surveys have been conducted on Doctor of Medicine (MD) degree students in Canada [15], the United Kingdom [16], and Germany [18], all of which primarily focused on how students' perceptions of AI may affect their choice of career in radiology. These studies were limited by their small sample sizes, with sampling performed only at select medical institutions. Furthermore, as the roles of various health care providers are redefined in modern medicine, the integration of AI will require interdisciplinary collaboration of stakeholders in health care, which includes not only physicians but also allied health care professionals. Collecting data on a diverse mix of allied health care students is critical, as allied health care professionals make up most of the health care professionals aged <30 years in Canada [19].

Objectives

There is currently no literature exploring the perspectives of entry-to-practice health care students on AI. This work presents the results of a nationwide survey of these students in Canada. Therefore, the goals and impacts of this survey are 3-fold. First, this work aims to explore and identify gaps in knowledge that Canadian health care students have regarding AI. This will allow us to explore the potential challenges related to knowledge acquisition of AI in health care education, and this information can, in turn, be used to inform decision-makers to better address these challenges. Second, this work aims to explore the potential differences in knowledge and perspectives on AI between students in different health care disciplines. Knowledge gaps in AI between future end users must be identified to facilitate effective communication and, in turn, improve patient safety and quality of care. Finally, this work provides an opportunity to present students' suggestions on how to incorporate AI literacy into the health care curriculum.

Methods

Ethics

This prospective anonymous web-based survey study received ethics approval from the local institutional behavioral research ethics board (H20-03339). Participants were informed at the beginning of the survey that the survey completion would imply their informed consent.

Study Cohort

The inclusion criteria were being aged ≥18 years and being currently enrolled in a Canadian entry-to-practice health care program at the time of this study [20]. We excluded responses from students studying outside Canada or those not in an entry-to-practice program.

Survey Design

The survey was developed from a narrative literature review of topics in attitudinal surveys on AI [15,16,18,21,22]. Attitudinal questions such as Likert scale belief questions were adopted from previous surveys directed toward radiology residents and US citizens [16,21]. The survey was piloted within a small group from the same university, involving 5 MD students, 2 occupational therapy (OT) students, and 2 clinicians (neurologists and occupational therapists). Questions were revised for clarity according to feedback from the pilot group.

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The final survey comprised 15 items, including multiple-choice questions, pick-group-rank questions, 11-point Likert scale items, slider scale questions, and narrative questions (Multimedia Appendix 1) and was available in both English and French. Respondents were first asked to provide their own definition of AI and then given the following definition of AI to refer to for the remainder of their responses: "software that can learn from experience, adjust to new inputs, and make decisions" [23]. The survey focused on six broad topics: (1) demographics information, including the institution of training, program, age, gender, and level of education; (2) self-reported perceived understanding of AI; (3) attitudes toward the impact of AI on the respondent's field; (4) whether the respondent wanted basic literacy in AI to be incorporated into their program's curriculum; (5) priorities in AI literacy education; and (6) the settings and amount of time the students were willing to spend to acquire basic AI literacy.

Survey Distribution

We used snowball and convenience sampling methods [24] by distributing an email with a description and a link to the web-based survey to representatives from 18 Canadian schools (Table 1). Allied health programs were selected from the Health Care Provider Taxonomy [20]. Respondents also had the option to choose *other* for the program. Any *other* programs with >20 respondents were included for analysis (eg, midwifery). The survey was hosted on an institutional survey platform (Qualtrics). Representatives were asked to distribute the survey among their student bodies. For example, at our home institution, the survey was distributed by the Faculty of Medicine, after internal approvals, to all the currently enrolled undergraduate MD students via the school mailing lists (a pool of 1152 students). For all institutions, 1 to 2 reminders were sent to the students 1 month after initial contact. Participation in this anonymous survey was voluntary and incentivized with a random draw for a gift card. Data were collected from January 2021 to June 2021.

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Table 1. Survey respondent demographic statistics (N=2167).

Characteristic	Values, n (%)
Gender	
Female	1355 (62.53)
Male	805 (37.15)
Nonbinary	7 (0.32)
Age group (years)	
21-25	1217 (56.16)
26-30	492 (22.7)
31-35	136 (6.28)
36-40	71 (3.28)
41-45	20 (0.92)
46-50	4 (0.18)
≥50	7 (0.32)
<21	220 (10.15)
School	
Dalhousie University	85 (3.92)
Laurentian University	60 (2.77)
McGill University	44 (2.03)
McMaster University	31 (1.43)
Memorial University of Newfoundland	20 (0.92)
Northern Ontario School of Medicine	62 (2.86)
Queen’s University	64 (2.95)
University of British Columbia	438 (20.21)
Université Laval	24 (1.11)
Université de Montréal	21 (0.97)
Université de Sherbrooke	18 (0.83)
University of Alberta	296 (13.66)
University of Calgary	143 (6.6)
University of Manitoba	96 (4.43)
University of Ottawa	19 (0.88)
University of Toronto	458 (21.14)
University of Saskatchewan	186 (8.58)
Western University	97 (4.48)
Other	5 (0.23)
Program	
Audiology	15 (0.69)
Dentistry	77 (3.55)
Dietetics	1 (0.05)
Genetics counseling	35 (1.62)
Medical doctorate	683 (31.52)
Medical Laboratory Science	10 (0.46)
Midwifery	22 (1.02)
Nursing	514 (23.72)

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Characteristic	Values, n (%)
Occupational therapy	249 (11.49)
Pharmacy	159 (7.34)
Physical therapy	217 (10.01)
Social work	43 (1.98)
Speech language pathology	142 (6.55)
Year level	
First year	479 (22.1)
Second year	680 (31.38)
Third year	550 (25.38)
Fourth year	335 (15.46)
Other	30 (1.38)
Highest degree of education completed	
Bachelor's degree	1160 (53.53)
Diploma or certificate	27 (1.25)
High school	371 (17.12)
Master's degree	438 (20.21)
PhD degree	166 (7.66)
Other	5 (0.23)

Statistical Analysis

Participant responses were included in the analysis if they completed 65% of the questions, as this completion rate indicated completion beyond demographics for the response to be meaningful. In addition, survey responses lacking programmatic information, or those which indicated non–health care fields, were excluded. Responses were checked for duplication by checking for IP addresses and response similarities. Duplicate responses were subsequently removed. Programs with <20 responses were removed from the between-program analysis. Age was categorized into the following eight groups: <21 years, 21 to 25 years, 26 to 30 years, 31 to 35 years, 36 to 40 years, 41 to 45 years, 46 to 50 years, and >50 years. For quantitative measures, the number of respondents and the percentage of total respondents were reported. The normality of AI perception distributions could not be established using the Shapiro–Wilk test (W=0.953; P<.001). Therefore, Kruskal–Wallis analyses were performed to test for differences in attitude by age, gender, year of training, previous degree, professional interests, and regional variations, with the significance level determined by P<.001. When significant differences were found, post hoc Conover tests with Holm-adjusted P values were performed to determine which groups differed from each other. All analyses were performed using Python (version 3.8, Python Software Foundation). Data management and statistical testing were conducted using the following packages: tableone [25], scikit-learn [26], numpy [27], pandas [28], matplotlib [29], scipy [30]. Our code is available on GitHub [31]. For the definition of AI, 2 members of the research team (DL and AG) with training in engineering and health sciences, respectively, reviewed all responses and classified the definitions as accurate, partially accurate, inaccurate, or do not know. The correctness of the AI definition was assessed based on the following definition of AI: "software that can learn from experience, adjust to new inputs, and make decisions" [23]. For example, a response would be marked as incorrect if it included generic responses such as "AI is anything related to computers," partially correct if the respondent described an aspect of AI such as machine learning, and correct if the respondent described machine intelligence in any manner. Discrepancies were flagged and reconciled with a third member (MT) of the team. Thematic analysis of free-text data on sentiments toward AI was conducted manually by 2 members (DL and AG) of the research team. Themes were grouped by these 2 members, and discrepancies were reconciled with a third member of the team (MT).

Results

Overview

The study was initiated in December 2020, approved by the ethics board on January 25, 2021, and data were collected between January 25 and May 31, 2021. The total number of survey respondents was 2167 at the time of submission of the manuscript, and all analyses were completed using data from 2167 data points. We expect that the results will be published in spring 2022.

Respondent Demographics

A total of 2947 responses were collected from 18 universities across Canada. Out of these 2947 responses, 780 (26.47%; 261, 33.5% because of duplicate responses, 442, 56.7% because of incompletion, 1, 0.1% because of invalid age response, and 76,

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9.7% for not indicating programmatic information or not being in an entry-to-practice program) were removed from the analysis. Descriptive statistics and nonparametric statistics were generated using 73.53% (2167/2947) valid responses, representing all 10 provinces across Canada (see Table 1 for demographic details). Response rates per discipline were estimated (Table 2). There were no significant demographic differences for those with complete surveys versus incomplete surveys (ie, not providing further information other than demographics).

Table 2. Estimated response rate per program.

Program	Estimated total number of students in Canada across all training years[a], N	Survey sample and estimated survey representation, n (%)
Dentistry	1695	77 (4.5)
Genetics counseling	40	35 (87.5)
MD[b]	10,179	683 (6.7)
Midwifery	338	22 (6.5)
Nursing	9746	514 (5.3)
Occupational therapy	2058	249 (12.1)
Pharmacy	4610	159 (3.4)
Physical therapy	2106	217 (10.3)
Social work	4052	43 (1.1)
Speech language pathology	749	142 (19)

[a]The total number of students was estimated from enrollment statistics from the 18 schools included in the study.

[b]MD: Doctor of Medicine.

General Attitudes and Knowledge

When asked to define AI, more than half of the respondents did not know what AI was (1107/2167, 51.08%) or had an inaccurate understanding of it (676/2167, 31.2%; Multimedia Appendix 2). Results stratifying respondents with and without an accurate understanding of the definition of AI are described in the *Post Hoc Analyses* section. Following the first open-ended question asking participants to define AI, the rest of the responses were based on the following definition of AI provided to the participants: "software that can learn from experience, adjust to new inputs, and make decisions" [19]. Overall, most reported a positive outlook on the development of AI in their respective health care fields, believed that AI would have an impact on their careers, and predicted integration of AI in their fields within the next 5 or 10 years (Multimedia Appendices 2-5).

Using the Kruskal–Wallis test, no statistically significant differences were found in attitude toward AI between the different age groups (H=12.35; P=.09), gender (H=4.76; P=.09), or region (H=9.007; P=.61) groups. Statistically significant differences were found in attitudes toward AI for participants from different groups based on their year of training (H=21.359; P<.001), degree of education completed (H=32.35; P<.001), program (H=103.82; P<.001), institution of training (H=44.06; P<.001), and professional interests (H=41.08; P<.001). Students who were less advanced in their training had less favorable outlooks toward AI than upper-year students (P<.001; Figure 1). Students who had already completed a bachelor's or master's degree had more positive outlooks on AI than students who had completed high school only (P<.001) or had a PhD degree (P=.004). Respondents interested in pursuing research or business as part of their careers had a more favorable attitude toward AI than those wishing to focus on clinical work (P<.001).

Students in medicine, dentistry, and physical therapy (PT) had similar positive outlooks regarding AI development in their fields, differing statistically from those in most other health care fields, such as genetics counseling, midwifery, nursing, OT, pharmacy, social work, and speech language pathology (SLP; Figure 2).

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Figure 1. Attitude toward artificial intelligence (AI) stratified by (A) current year of study, (B) highest level of education completed, and (C) professional interests.

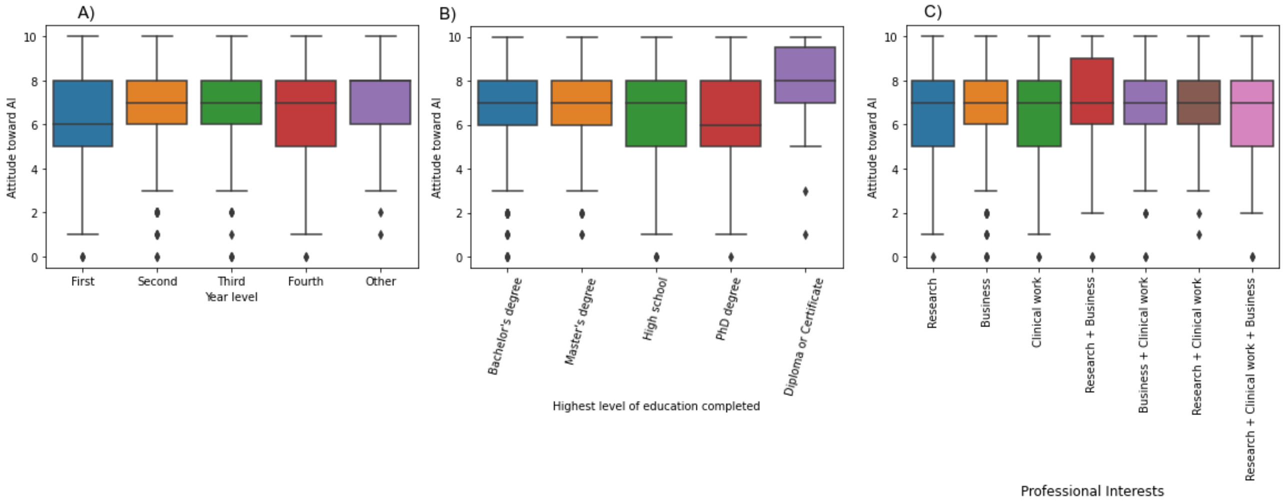
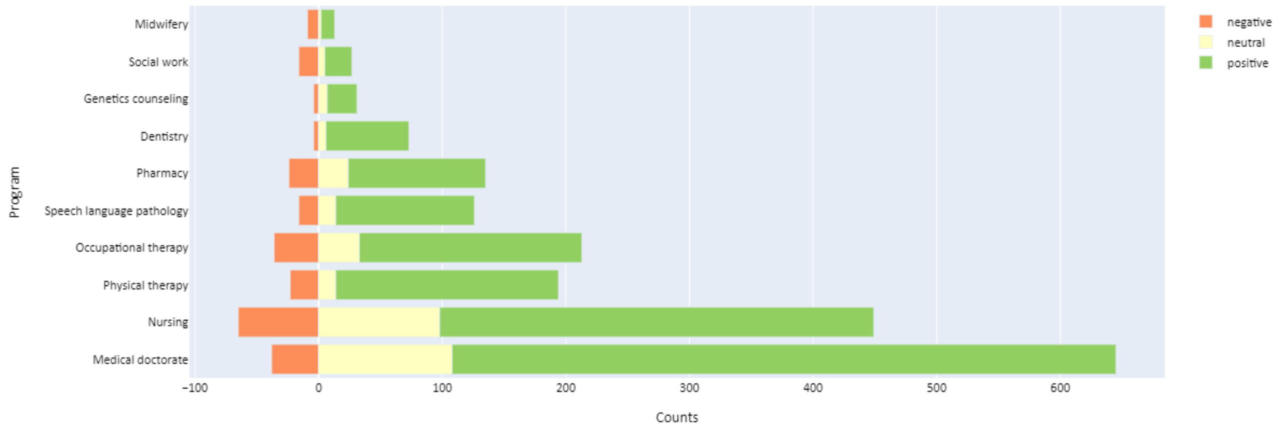


Figure 2. Attitude toward artificial intelligence (AI) by program or profession.



Overall, students in different health care programs differed in their opinions on whether AI would affect their careers (*H*=136.82; *P*<.001; Figure 3). Students studying medicine were much more likely to agree that AI would have an impact on their careers than other health care students (*P*<.001). Regardless of the health care program, students believed they needed to gain basic literacy in AI (Multimedia Appendix 3). On the basis of Likert scale self-rated responses, students differed in their self-rated understanding of AI ethics (*H*=127.705; *P*<.001). Students in PT and dentistry programs ranked higher in their perception of understanding of the ethical implications of AI than other health care students (*P*<.001), whereas students in medicine and midwifery ranked lower in their understanding of the ethical implications of AI in their fields (*P*<.001).

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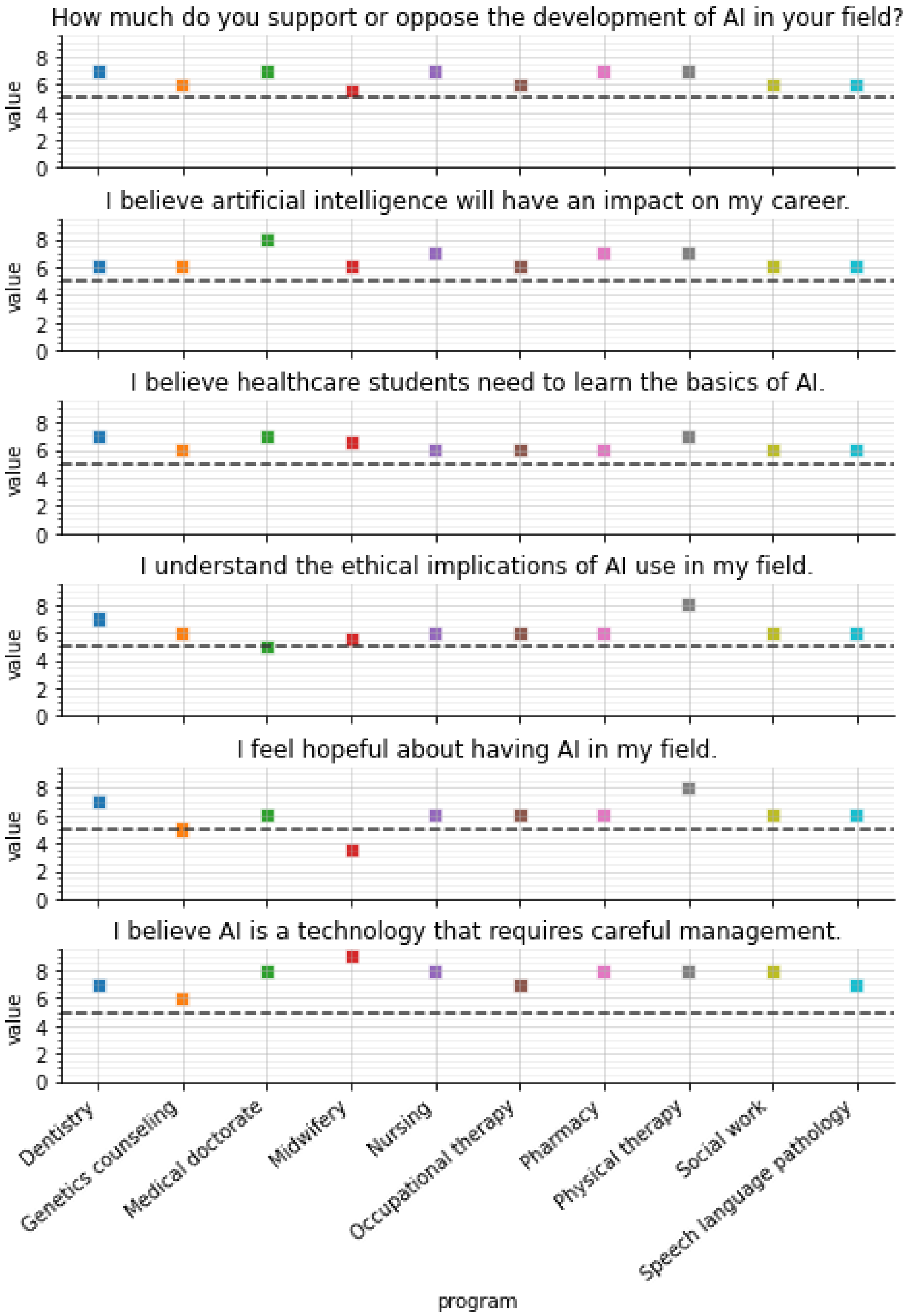
Figure 3. Responses to Likert scale questions by program. AI: artificial intelligence.



In terms of hopefulness toward AI development, students differed in their opinions by health discipline (*H*=98.382; *P*<.001). Specifically, students in midwifery felt significantly less hopeful than other health care students (*P*<.001), whereas students in dentistry and PT were more hopeful about AI than other health care students (*P*=.009). Students in PT and dentistry were most worried about the development of AI in their fields (*P*=.002), whereas students in midwifery were least worried about the development of AI in their field compared with other health care students (*P*=.003). Most students (1942/2167, 89.62%) from all health care fields believed that AI was a technology requiring careful management, with students in medicine, nursing, pharmacy, and midwifery sharing stronger views on this than other health care students (*P*<.001).

Thematic Analysis

Thematic analysis of responses to the question “use one word or sentence to describe how you feel about AI in your field,” revealed three key themes: cautious optimism, uneducated and uncertain, and concerns about being replaced by AI.

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Cautious Optimism

Across all 10 health care programs, there were respondents who expressed optimism and hopefulness toward AI. Students believed that “[AI] will greatly improve the practice of medicine to be more efficient and reliable” [an MD student] and “[it] could prevent mistakes and increase efficiency” [a midwifery student]. There was a sense that “It may be inevitable for AI to be involved in my field to some degree in the future” [a social work student]. Caution was expressed in conjunction with these responses as students were aware that “AI needs to be developed and implemented carefully as to not take away the individualization of...healthcare” [a midwifery student].

MD students generally had more positive sentiments toward AI. Many of them would support the development of AI if patient outcomes could be improved:

> *If it helps patient outcomes, I’m in.* [an MD student]

Another MD student mentioned the following:

> *If AI is used for enhancement of the field rather than replacement of skilled workers then my comfort increases, however I am apprehensive of the potential misuse of the technology and the risk of job loss to physicians.*

Nursing students were generally optimistic toward AI and had more comments on risks associated with AI than those from other programs:

> *AI can pose huge confidentiality issues for patient healthcare records.* [a nursing student]

Another nursing student stated the following:

> *I think it can have great impacts but still need to be monitored for safety.*

Students in OT and PT frequently mentioned AI as a tool that will “do boring repetitive things for humans” [an OT student]. One of the PT students mentioned that AI will “replace high-risk treatments.” Students in both programs agreed that AI would “greatly improve work efficiency” [an OT student].

Dentistry students generally had more positive attitudes toward AI. Most responses were single words, such as “good” and “exciting.” Some students commented that “[AI is] the trend of future development.” Genetics counseling students did not have program-specific variations from the thematic analysis.

Although there were students in all health care programs who opposed the development of AI in their fields, some social work students more strongly voiced this in their responses that there is “no role [for AI].” Another student said, “It’s a threat to my profession.” However, the main ethos from social work students aligned with the general theme of cautious optimism.

Students in midwifery had more negative attitudes toward AI:

> *I believe that AI has already had a negative impact in my field.*

Another student mentioned the following:

> *It does not have a place in midwifery, you cannot teach empathy and comfort measures for a woman in labour.*

This was echoed by another student who said, “It would probably make parts of my job more complicated.” More frequently occurring words used by midwifery students to describe feelings toward AI included “scared,” “dangerous if not careful,” and “apprehensive.”

Uneducated and Uncertain

Permutations of this quote frequently appeared in the responses:

> *I feel under-informed and under-educated.* [an OT student]

Many students expressed feeling “unsure,” “uncertain,” or “there is no feeling” toward AI (PT students). Health care students also expressed being uncertain about how AI would be applicable to their fields, if at all:

> *I don’t know if AI would be applicable in Speech pathology.* [an SLP student]
>
> *I don’t see [AI] having a huge impact in pharmacy in the near future.* [a pharmacy student]
>
> *I believe it will be able to significantly help with dental lab work but don’t see much clinical applicability.* [a dentistry student]
>
> *I don’t really care because I don’t understand how it applies to me.* [an MD student]

Students also reported not having given much thought to the idea of AI in their fields. A nursing student stated the following:

> *I have not learnt much of AI and how it can be used in nursing, this survey has sparked my interest and it is something I am going to read up on.*

A pharmacy student also mentioned the lack of opportunities to learn more about AI in their fields:

> *I always hear about it but I don’t see a lot of opportunities to learn about it.*

Regarding having to learn about AI, MD students reported concerns over having to learn more on top of their already intensive curriculum:

> *It scares me that MD students/healthcare professionals on top of everything else will one day have to learn AI, this is similar to learning statistics to be able to do research properly. It is simply not our field and expertise and it stresses me out.*

SLP students were doubtful about the role that AI will play in their field. One of the students mentioned that they were “doubtful about the role AI could even play.” Others went into details about the inapplicability of AI:

> *I don’t think AI is going to be beneficial/used in the field of speech and language considering the current limitations relating to automatic speech recognition (AI can’t easily recognize “atypical” speech).*

Another student stated the following:

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> *I think AI may play a large role in training future clinicians, but not in clinical work or practice.*

Concerns About Replacement

Even when unprompted, respondents often cited aspects of their jobs that cannot be replaced by AI:

> *Although helpful, it can't replace human emotion.* [a nursing student]

A genetics counseling student stated the following:

> *I feel that as I am in a counselling field that emphasizes human emotion, AI is not very relevant. It may be useful for the technological pipelines that generate and interpret genetic information but won't be able to fill the role of a genetic counsellor.*

Worries about job loss were a common theme among health care students:

> *I am a bit worried I may get replaced.* [a social work student]

> *I hope AI doesn't completely devour my field.* [a pharmacy student]

> *I am nervous it will replace jobs and that it may have negative ethical implications.* [a nursing student]

Pharmacy students shared many examples of how AI could be applied in their fields:

> *I think AI has the potential to take some of the technical work off of pharmacists and allow us to focus on more clinical work—exciting potential.*

> *It can be helpful when dispensing high-volume medications in a timely manner, especially when short-staffed.*

Many also shared concerns over job replacement:

> *I think AI is emerging in the pharmacy world and can simplify a lot of routine jobs but also has the potential to take over a lot of human tasks which could be concerning for the job market in the future.*

Another student emphasized that although AI has applications in pharmacy, it should not replace jobs:

> *[AI] may be useful to carry out technical tasks but all clinical work should be carried out by professionals. AI should [be] an aid, not a replacement of labour.*

Curriculum Integration

Over half of the respondents (1373/2167, 63.36%) believed that gaining basic literacy in AI should be part of their curriculum. Importantly, this sentiment was shared with the cohort of students (235/2167, 10.84%) who opposed the development of AI in their fields. In this cohort, 44.7% (105/235) believed that health care students needed to learn the basics of AI and that it should be within their program curricula. Regarding how AI literacy should be incorporated into their programs, respondents preferred either a multiple-workshop series (638/2167, 29.44%), 1- or 2-hour workshops (501/2167, 23.12%), and a 1-day course (349/2167, 16.11%). A minority (148/2167, 6.83%) expressed interest in pursuing graduate-level education to learn more about AI. The rest of the respondents felt that a combination of the above would be sufficient (531/2167, 24.5%; Multimedia Appendix 4).

When asked to rank important objectives that should be covered in AI literacy education, the following three objectives (in order of ranked importance) were most frequently selected by respondents: *identify when technology is appropriate for a given clinical context*, *identify the ethical implications of using AI in the clinical context*, and *identify ways AI can improve health care quality improvement* (Figure 4). For those who chose *other* objectives, some wanted to learn how AI may affect billing and patient turnover as well as data privacy, security, and legal issues related to AI use. See Multimedia Appendix 5 for all objectives ranked per program.

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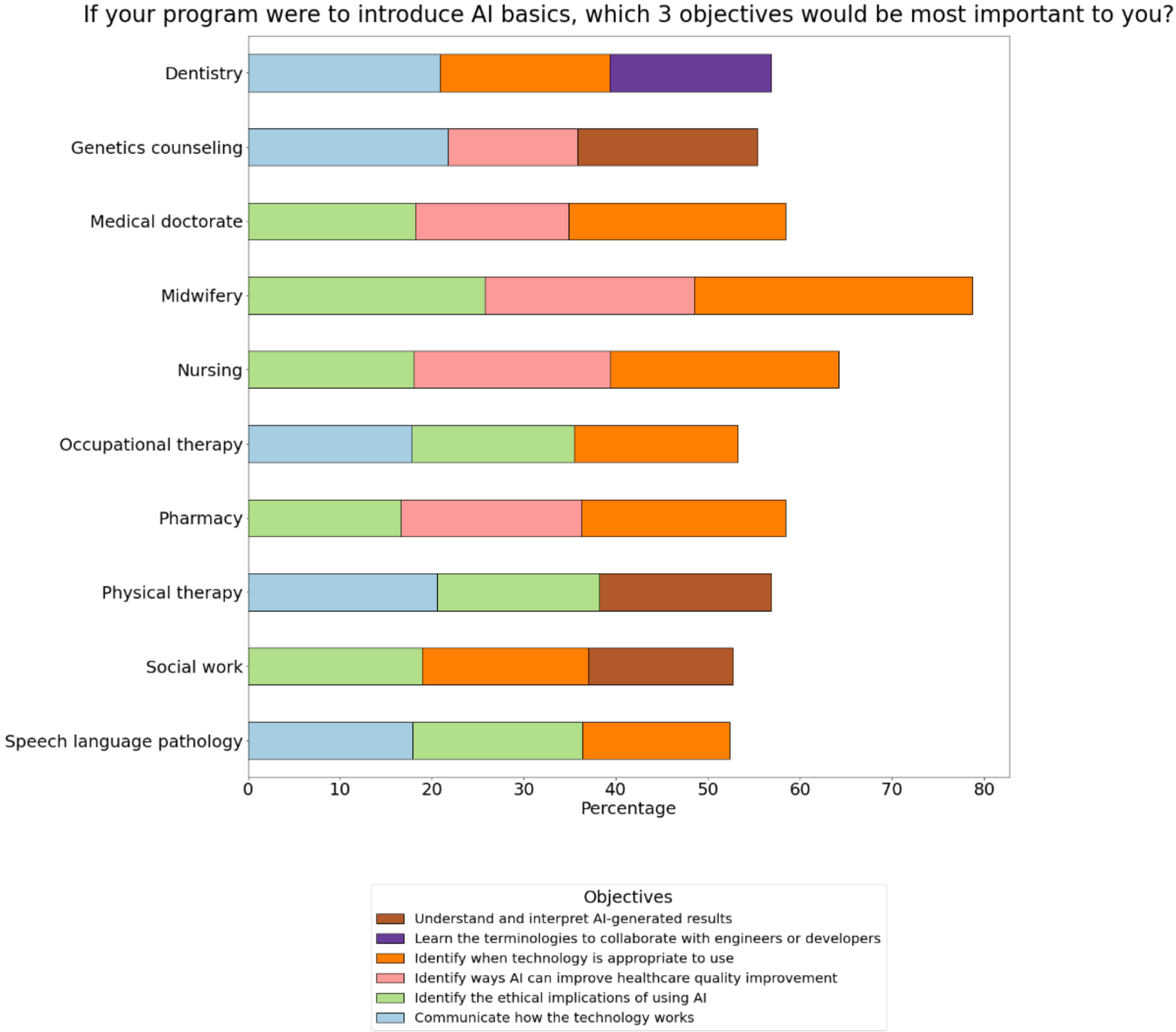
Figure 4. Top 3 objectives ranked important per program.



Post Hoc Analyses

Only a minority of respondents (338/2167, 15.6%) provided a correct definition of AI. To better understand how survey responses differed by familiarity with AI, we assigned respondents within our sample, post hoc, to one of three levels based on their initial definitions of AI: *low* (unable to provide a definition of AI), *intermediate* (provided an incorrect or partially incorrect definition of AI), *high* (provided a correct definition of AI). We repeated our quantitative analyses while stratifying by AI familiarity.

Students with high and intermediate familiarity had a more positive outlook (*P*<.001; Figure 5) than those with low familiarity (*P*<.001). Students with high familiarity also believed that AI would have an impact on their careers sooner than their peers with less familiarity with AI (*P*=.002). Students with a low level of familiarity were more likely to indicate that AI literacy should be part of their curriculum when compared with students with a high level of familiarity (*P*<.001).

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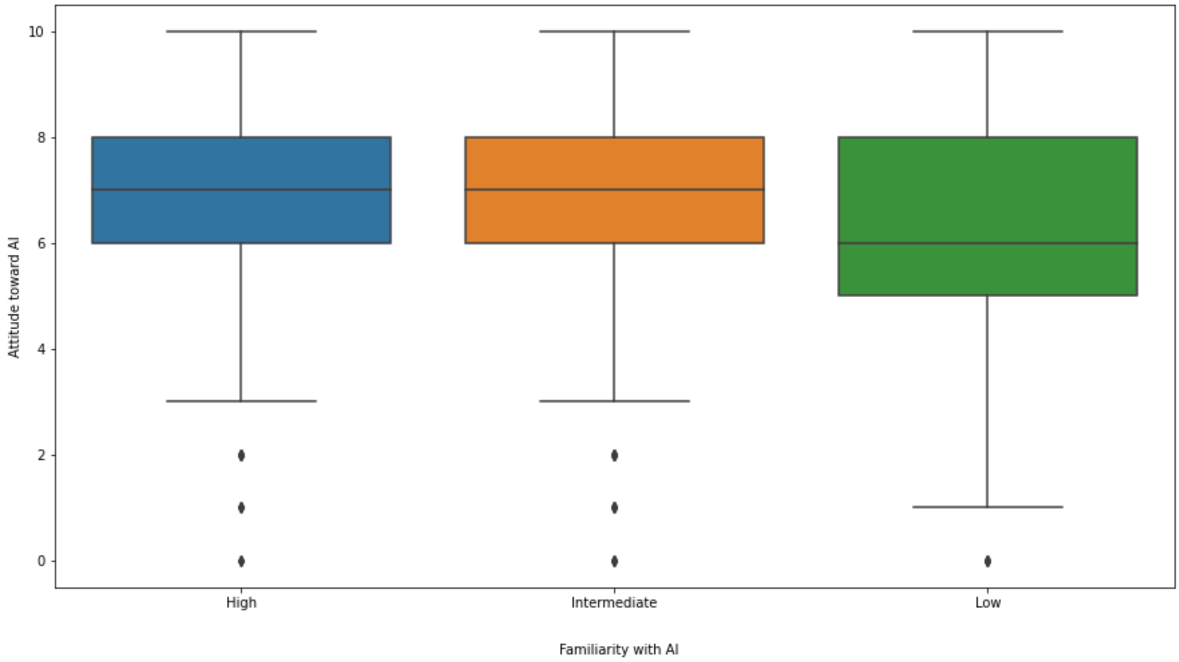
Figure 5. Attitudes toward artificial intelligence (AI), stratified by familiarity with AI.



Qualitative findings stratified by AI knowledge similarly mirrored findings from the quantitative analysis: students who responded with "I don't know" when asked to define AI were more likely to feel uncertain and cautious toward AI. Common sentiments in this subgroup included "I'm not sure what to expect," "Concerning if it would completely replace nurses," and "Afraid it will make some future careers in medicine obsolete." Subgroups that ventured into a definition for AI (regardless of whether the responses were correct, incorrect, or partially correct) did not differ markedly from the general sentiment analysis.

Discussion

Principal Findings

This is the first study to investigate the views of health care students from different health care programs on AI in health care. We found that health care students generally held cautious optimism toward AI in their fields, although more than half of the health care students indicated not knowing what AI was or how it may be relevant in their fields. Overall, we found that health care students felt unprepared and uneducated about AI, which may have contributed to their fear and anxiety over this topic. This study is distinct from previous work surveying MD student perspectives on AI in health care [16,18,32] because of its size, nationwide cohort, and scope across different health care disciplines.

Consistent with findings from other MD student or resident surveys on AI [15,18,33], we found that health care students had limited knowledge of AI. The lack of understanding of AI indicates an urgent need for education, as health care providers may increasingly need to use AI applications in their practices. Not understanding how AI may be integrated into their fields or how to interpret AI-generated results may hinder care delivery and lead to fear or distrust of such applications [15,16,34]. A total of 2 previous surveys assessing medical students' self-perceived understanding of AI also found limited AI-related knowledge among respondents. A 2020 European survey showed that only one-third of the medical students surveyed stated that they had a basic knowledge of AI [16]. A 2021 survey of medical students in Ontario showed that respondents believed that they understood what *AI* meant; however, when asked about specific terminologies related to AI, such as machine learning or neural networks, students did not understand them [22]. A major limitation of these studies was that knowledge of AI was assessed using the self-reported perception of AI understanding using Likert scales. Our study offers the first glimpse into a less subjective view of health care students' understanding of AI. Over half of the survey respondents indicated that they did not know what AI was. This finding suggests that our sample differed widely in their knowledge of AI. In addition, the respondents' reported perceptions of AI might vary systematically with their knowledge of AI.

We identified that most Canadian health care students felt equally hopeful and worried about the role of AI in their fields, which may be related to a lack of understanding of AI. A similar mixed sentiment was previously expressed by MD students from the United Kingdom [16] and by practicing health professionals in France and the United States [33,35]. Health care workers appear hopeful that the incorporation of AI will bring improvements in diagnostic accuracy [34] and patient monitoring [33] and reductions in medical errors [36] and improve the accessibility of care in medically deficient regions [33]. Worries regarding the incorporation of AI into health care may be attributable to the potential for replacement of health professionals [15] and additional knowledge requirements in their fields [37]. These ideas were reflected in our respondents' willingness to adopt any intervention that could support patient care while also expressing concerns about future employment and lack of knowledge regarding AI.

Attitudes toward AI differed among the following demographic variables: (1) year of training, (2) highest degree of education

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completed, (3) university, (4) professional interests, and (5) profession. Students in the earlier years of their training had less favorable outlooks toward AI than upper-year students. The increased clinical exposure in later years of training [38,39] may explain this finding, where having observed how technology is used in situ may have dispelled misconceptions about the clinical utility of technology [38,39]. This survey also identified that students who had completed a bachelor's or master's degree had a more positive outlook on AI than students who had completed high school and, interestingly, a PhD. In fact, students with high school as their highest level of education did not differ significantly from students who had completed a PhD. There is evidence to suggest that there is a larger emphasis placed on AI application in higher education, with most research focusing on undergraduate students over postgraduate students [22]. In terms of professional interests, students who wished to pursue research or entrepreneurship in their careers had a more favorable outlook on AI than those who wished to focus on clinical work. Laï et al [33] previously found that industry professionals and researchers are the driving force for AI implementation as these individuals are mainly focused on development, whereas clinicians consider themselves as users of AI and tend to remain more pragmatic, especially when many have yet to see AI applications being used successfully and ethically in clinical medicine. Health care students who are interested in research and business may have experience in these fields and, therefore, may have a line of thinking that is more closely aligned with developers. This contrasts with students mainly interested in clinical work, who may have more uncertainties regarding AI in health care or fear that AI may be applied at the expense of human connections in disciplines with an emphasis on direct patient interactions.

When asked which 3 objectives would be most important to include when introducing AI basics to their educational programs, students from different disciplines ranked the objectives differently. Although the exact order of the objectives might have differed slightly among the different professions, most professions consistently ranked the following among the top objectives: *identify what technology is appropriate for a given clinical context*, *identify the ethical implications of using AI in clinical contexts*, and *identify ways AI can improve health care quality improvement*. This may indicate that basic AI programs should focus on these 3 objectives to meet the needs of student interests from multiple disciplines. Of note, dentistry students differed from other health care students in that 2 of the top-ranked objectives involved *communicating how the technology works* and *learning the terminologies to collaborate with engineers*. This may be because dentistry is a largely private practice in Canada, and thus, dentistry students are more business- and relationship-oriented. Rehabilitation professionals (OT, PT, and SLP) ranked *communicating how the technology works* as one of the top-ranked objectives, which may reflect their priority to communicate the underlying technology in ways that strengthen therapeutic alliance, as therapeutic alliance and rehabilitation adherence were found to be positively correlated [40,41]. Genetics counseling students were especially interested in learning about interpreting AI-generated results, which was not surprising, given that this profession involves interpreting genetic testing results.

The results revealed that across all health care programs, respondents felt uneducated about AI in general. This may have to do with the fact that although some Canadian health professional institutions include AI objectives in their core curriculum, many others do not [32,42]. When asked to comment on their feelings toward AI, students in medicine and nursing were generally optimistic toward the role of AI, whereas students in midwifery, for example, had more negative attitudes. A possible reason for these differences can be explained in the study by Doğaner et al [43], which found that health science students feel that although AI will benefit technology and health, it will negatively affect employment and sociology. These findings were reflected in the student responses in our study, as most negative responses revolved around the themes of employment and the fear of losing human connections. These feelings may be because of a lack of understanding of AI but should not be discounted; further research should be conducted to address these apprehensions [16].

With most health care students predicting that AI would be integrated within their field in the next 5 to 10 years, the lack of introduction to AI in health care curricula is especially striking. Fears and misconceptions related to AI replacing health care professionals could be addressed and prevented by introducing AI into health care education. Regardless of the differences in attitudes among students from different professions, students will benefit from additional education on the topic. Although to our knowledge, no work to date has focused specifically on the best ways to deliver AI literacy in health care education, students may share similar learning preferences to statistics literacy. For instance, previous work suggests that health care students prefer that statistics be incorporated into their education by using a variety of media [44] using content that will be relevant to their future practice [44,45]. Previous investigators have explored a variety of delivery formats, including blended [46], problem-based [47], competition-oriented [48], and a mix of lecture and seminar [44] models in statistical education. Future research should investigate how insights into statistical education gleaned from research can be applied to AI literacy education.

An AI-friendly health care curriculum is essential as future health care providers will likely be responsible for the oversight of algorithmic interpretation of patients' health care data [49]. Beyond the health care curriculum, the integration of AI into clinical practice must be carefully evaluated. Gaps in knowledge among end users of AI applications in different health care disciplines must be identified to ensure the safety and effectiveness of AI applications in patient care. This is necessary, given the interdisciplinary nature of AI, as well as the current disconnect in the level of understanding between health care professionals and their computer science colleagues. Future end users must be digitally competent and confident in data literacy and their ability to use and interpret AI applications. Therefore, it is imperative to include a basic understanding of AI in health care education, as health care students represent the future generation of AI end users.

The limitations of this study include recruitment and participation bias. Recruitment was conducted by MD student representatives from Canadian medical schools, potentially

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limiting recruitment from other health care programs. There was less representation from institutions that did not have MD programs, except Laurentian University. There was also less representation from men, those aged >40 years, and those from rural and territorial regions. This is important as AI in health care can potentially improve equity and access; however, equitable representation needs to be in place for its success. Those who already have interest, knowledge, or participation in AI may have been more inclined to participate in the study. Furthermore, responses on perceived understanding, attitudes, and perceptions of AI may be biased by the degree of exposure to AI in the respective fields and institutions. Compared with the number of physicians and allied health professionals in the workforce [19], MD students were overrepresented in the study, whereas nurses and allied health workers were underrepresented.

Conclusions

This study adds to the current literature on health care students' attitudes toward AI and their learning preferences and self-identified areas of knowledge gap. Canadian health care students were cautiously optimistic about the role of AI in their fields; however, many felt uneducated about this topic. Health care students in different programs identified different curricular needs, and such program-specific needs should be considered with the curriculum integration of AI. The findings from this nationwide survey contribute to our understanding of knowledge gaps in AI among students and will advance education across different health care professions.

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Authors' Contributions

MT, RS, and OY planned the study. MT, RS, OY, DL, AG, ZH, RH, AA, SE, CH, SH, DK, KMM, SM, VM, and YT assisted with the study recruitment process. MT analyzed the data, with contributions from DL, AG, ZH, RH, and ML. MT wrote the first draft of the manuscript. DK, OY, RS, TJ, and TSF provided important revisions to the manuscript. All authors contributed to data interpretation and critically reviewed and approved the final manuscript.

Conflicts of Interest

None declared.

Multimedia Appendix 1
Full survey.
[DOCX File , 26 KB - mededu_v8i1e33390_app1.docx]

Multimedia Appendix 2
Respondent familiarity with artificial intelligence.
[PNG File , 26 KB - mededu_v8i1e33390_app2.png]

Multimedia Appendix 3
Respondent belief on artificial intelligence curriculum integration.
[PNG File , 22 KB - mededu_v8i1e33390_app3.png]

Multimedia Appendix 4
Respondent preference on artificial intelligence education format.
[PNG File , 65 KB - mededu_v8i1e33390_app4.png]

Multimedia Appendix 5
Objectives ranked important per program.
[PNG File , 141 KB - mededu_v8i1e33390_app5.png]

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Abbreviations

AI: artificial intelligence
DL: deep learning
MD: Doctor of Medicine
OT: occupational therapy
PT: physical therapy
SLP: speech language pathology

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Original Paper

Piloting an Innovative Concept of e–Mental Health and mHealth Workshops With Medical Students Using a Participatory Co-design Approach and App Prototyping: Case Study

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Abstract

Background: Medical students show low levels of e–mental health literacy. Moreover, there is a high prevalence of common mental illnesses among medical students. Mobile health (mHealth) apps can be used to maintain and promote medical students' well-being. To date, the potential of mHealth apps for promoting mental health among medical students is largely untapped because they seem to lack familiarity with mHealth. In addition, little is known about medical students' preferences regarding mHealth apps for mental health promotion. There is a need for guidance on how to promote competence-based learning on mHealth apps in medical education.

Objective: The aim of this case study is to pilot an innovative concept for an educative workshop following a participatory co-design approach and to explore medical students' preferences and ideas for mHealth apps through the design of a hypothetical prototype.

Methods: We conducted a face-to-face co-design workshop within an elective subject with 26 participants enrolled at a medical school in Germany on 5 consecutive days in early March 2020. The aim of the workshop was to apply the knowledge acquired from the lessons on e–mental health and mHealth app development. Activities during the workshop included group work, plenary discussions, storyboarding, developing personas (prototypical users), and designing prototypes of mHealth apps. The workshop was documented in written and digitalized form with the students' permission.

Results: The participants' feedback suggests that the co-design workshop was well-received. The medical students presented a variety of ideas for the design of mHealth apps. Among the common themes that all groups highlighted in their prototypes were personalization, data security, and the importance of scientific evaluation.

Conclusions: Overall, this case study indicates the feasibility and acceptance of a participatory design workshop for medical students. The students made suggestions for improvements at future workshops (eg, use of free prototype software, shift to e-learning, and more time for group work). Our results can be (and have already been) used as a starting point for future co-design workshops to promote competence-based collaborative learning on digital health topics in medical education.

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KEYWORDS

participatory design; co-design; mHealth; medical student; eHealth; medical education; mental health; mobile phone

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Introduction

Background: Medical Students and the Potential of Mobile Health Apps

Medical students' poor mental health remains a worldwide challenge. Despite the high prevalence of mental illness among medical students [1], they are less likely to seek help than age-matched controls [2]. Moreover, they encounter additional hurdles when seeking help, such as fear of stigmatization or disadvantages for their prospective career [2-4]. Thus, face-to-face counseling on campus might not be the appropriate option for all students. Mobile health (mHealth) apps could help reduce the treatment gap.

Previous research suggests that digital interventions can be an effective tool to promote university students' mental health [5]. They address several barriers such as fear of stigmatization and provide help independently of time and location [6-8]. Especially in the face of the ongoing COVID-19 pandemic, digital access to psychological support is more important than ever [9]. However, the uptake of suitable mHealth apps among college students remains relatively low [10,11]. Evidence of acceptance of mHealth apps, including mental health apps, among university students is still limited and inconclusive [5,12,13], especially regarding the subgroup of medical students [14].

A possible explanation for the low uptake of mHealth apps might be that existing mHealth apps do not reflect medical students' needs and preferences [15]. Understanding users' needs might help to increase the early acceptance and use of mHealth apps [16]. A further reason for the low uptake might be that medical students lack familiarity with mHealth apps. For instance, in a recent study, only 1.3% of the participating German medical and psychology students reported ever having used an mHealth app [15]. Moreover, medical students' understanding of several aspects concerning mHealth apps (eg, terminology) is limited [17-20]. This knowledge is of great relevance for medical students, from both user and health care provider perspective. In December 2019, the German government passed the Digital Healthcare Act, which allows for the prescription of medical apps, including mental health apps [21]. As future health care providers, medical students will influence digital health care by prescribing mHealth apps to their patients [15]. Thus, they play a key role in facilitating the awareness and acceptance of mHealth apps in the general population. However, education on e–mental health and mHealth is still rare in medical curricula in Germany [22] as well as the rest of the world [23,24].

Given the relevance of the subject, educational concepts are needed to help implement mHealth in the medical curriculum.

Goals of This Case Study

The primary aim of this case study is to describe the piloting of a novel co-design workshop on mHealth and e–mental Health at a German medical school. We sought to explore the feasibility of co-design workshops as an educational concept and asked for participants' evaluations and suggestions for improvements regarding future co-design workshops (iterative development). Furthermore, we were interested in medical students' ideas and preferences for prototypes of mHealth apps and their application of the theoretical insights conveyed during the workshop.

Methods

Participants and Setting

The participants in this case study were preclinical and clinical medical students enrolled at the medical school of Heinrich Heine University Düsseldorf (HHU) in Germany. The inclusion criteria were age ≥18 years and registration for the elective course *e–Mental Health in Medical Education* (ie, the co-design workshop). Participation in this study was voluntary and did not affect the successful completion of the course. All participants gave their informed consent and agreed that their data (eg, their feedback and ideas for mHealth apps) could be used for research purposes. The study was approved by the ethical committee of the medical faculty of the University of Düsseldorf as part of a medical education project called *Healthy Learning in Düsseldorf*, which aims to investigate and improve medical students' mental health (study number: 4041).

The Co-design Workshop

We conducted the co-design workshop on 5 consecutive days on site from March 2 to 6, 2020, at the Faculty of Medicine at HHU, approximately 1 week before the first COVID-19 lockdown [25] and approximately 7 months before the directory for prescriptible digital health apps (*Verzeichnis für digitale Gesundheitsanwendungen* or Digital Health Applications Directory) was thrown open to the public in Germany [26]. The duration of the workshop was 30 hours in total, delivered over 5 days (11 AM to 5 PM from Monday to Friday), and it was held during the semester holidays. The workshop comprised lectures and supervised group work. Each day was designated for a specific topic or method of intervention development with respect to e–mental health (including participatory design approaches). Different modules guided the students through the development of a rapid prototype of their own mental health app (Table 1). In all, 3 guest lecturers were involved on days 2-4 to give insights into the development of mHealth apps. We conducted focus groups on the second and third day, which have been reported elsewhere [27].

Generally, each day of the workshop was structured in 2 parts. The first part consisted of introductory lectures on eHealth and participatory design methods. Moreover, the students were shown how to identify existing mHealth apps that are safe to use and are also of high quality. During the second part, the participants were divided into smaller groups to work through relevant literature on e–mental health and to develop their own hypothetical prototype for a mental health intervention. For this, they used a range of methods grounded in participatory design, design thinking, and target population–centered approaches to intervention development (Table 1). The students could create the concept for a native app or a web-based app (web version optimized for smartphone screens). They were asked to implement and consider everything that they deemed important.

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Table 1. Workshop contents.

Workshop day	Educational content	Activity
1	Introduction, components and types of guidance for mHealth[a] apps, quality criteria for mHealth apps, and legal framework	Introductory lecture, group work, presentations and plenary discussions on relevant literature, legal aspects, and identification of existing mHealth apps that are safe to use and are also of high quality (MARS-G[b] [28])
2	Acceptability and user orientation, co-design and participatory design methods, and strategies and model for designing mHealth apps	Expert lecture (building your own mHealth app and insights into a medical student's back pain app start-up), focus groups part 1 (reported elsewhere [27]), participatory approaches: think-aloud technique, and IDEAS[c] [29]
3	Gamification, development and adjustment of mHealth apps, and avatars	Expert lecture (assessment of avatar of a certified medical app for insomnia, *Somnio*), storyboarding, focus groups part 2 (reported elsewhere [27]), and prototyping avatars in groups
4	Acceptance-facilitating interventions, adherence-facilitation, and implementation	Expert lecture (web-based marketing), persona development, journey mapping, implementation mapping, prototyping, development of personas in groups, and mock-ups and prototypes
5	Presentations and workshop evaluation	Presentations of the mHealth app concepts, feedback questionnaires, and feedback round

[a]mHealth: mobile health.

[b]MARS-G: Mobile App Rating Scale, German version.

[c]IDEAS: Integrate, Design, Assess, and Share.

The first author (MD) and the last author (JAH) facilitated the workshop. JAH created the contents of the workshop with the support of MD. MD is a researcher and trained psychologist. JAH is a qualified psychologist with a background in medical psychology and an experienced researcher with focus on e–mental health and mHealth acceptance in different target groups, including medical students, as well as psychosocial stress research. Both facilitators conduct lectures for medical students and are involved in research on medical students' well-being. They took turns conducting lectures; the other observed and took field notes.

Prototypes of Apps: Knowledge Transfer

Each group, consisting of 3-7 students, focused on a different psychological problem for their hypothetical prototype of an mHealth app. Participants could choose from among the following 5 predetermined group topics, selected on the basis of their relevance for promoting mental health among medical students [1,30-32]:

- Depression and anxiety (transdiagnostic; students chose to focus on depressive symptoms)
- Stress management and subjective well-being
- Test anxiety and procrastination
- Insomnia (focus on health behavior and sleep quality)
- Psychosomatic conditions (self-management of chronic conditions; students chose to focus on gastrointestinal problems)

The medical students also had the opportunity to adapt their topic or propose other health conditions. All groups were supervised and provided with feedback during the development phase of their mHealth app.

Data Collection and Descriptive Analysis

During the workshop, the facilitators took notes and documented the workshop with photographs. All written and designed material was collected with the permission of the participants. In addition, the participants filled out a so-called logbook with predefined tasks mirroring the contents of the workshop. The logbook was also used to document their thoughts, ideas, and progress regarding the development of their prototype. The final segment of the workshop was devoted to the group presentations of the hypothetical app concepts. The presentations were rated based on predefined evaluation criteria (Textbox 1). The groups could choose to present their hypothetical prototypes using either a digital or flip chart presentation format. Of the 5 groups, 4 (80%) chose a digital presentation format. The presentations were analyzed, where possible, based on the extended version of the Unified Theory of Acceptance and Use of Technology, (UTAUT2 [33]) which has been introduced in the workshop. UTAUT2 has been postulated as a framework to understand and predict technology uptake and use. The model comprises 4 constructs from the original model (effort expectancy, facilitating conditions, performance expectancy, and social influence [34]) as well as 3 additional constructs (habit, hedonic motivation, and price value). The UTAUT2 model has been used in different contexts such as acceptance of electronic medical records or mobile learning technology [35-39]. Here, for instance, we looked at whether the medical students' prototypes included elements that foster hedonic motivation, such as gamification (Textbox 1). In some cases, we needed to extend the categories inductively based on the material because UTAUT2 did not provide a suitable category such as data security.

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Textbox 1. Criteria for the evaluation of medical students' presentations on their prototypes of mobile health apps.

Evaluation criteria

- Quality of the content
- Relevance for the target group and field of action
- Overall concept and presentation: comprehensibility, rationale, and logic
- Selection of content and components (based on evidence, empiricism, etc)
- Practical transfer: strategies for dissemination and execution
- Implementation
- Manner of presentation
- Visualization

At the end of the workshop, the participants completed a brief feedback questionnaire to evaluate the workshop. They were asked 3 questions regarding their perceived learning progress during the workshop on a scale from 1 (strongly disagree) to 6 (strongly agree), and they were given the opportunity to add suggestions for improvement in free text. In addition, feedback was collected during an oral feedback round and within a standardized anonymized evaluation form for lectures at medical schools. The latter is not reported in this study. The participants' feedback was used to make alterations and improvements for future workshops. Statistical analysis of the paper-based questionnaire data was performed using the software SPSS (version 25.0; IBM Corp).

Results

Sample Characteristics

In all, 26 participants (women: 17/26, 65%; men: 9/26, 35%) aged 18-30 years (mean 23.35, SD 3.73 years) took part in the workshop. All participants were medical students from the third to the ninth semester (mean 4.31, SD 1.87) at HHU. Of the 26 students, 16 (62%) were in their third semester, 4 (15%) were in their fifth semester, 5 (19%) were in their seventh semester, and 1 (4%) was in their ninth semester (median third semester). All (26/26, 100%) participants attended on all 5 days of the workshop and completed the course with a group presentation of their app concepts and prototypes (ie, there were no dropouts). The participants gave permission to use their intellectual work and feedback for research and publication purposes.

Common Themes: Narrative Insights From the Group Discussions and Group Work on the App Development

The common themes described in Textbox 2 have been derived either directly from the prototypes or have been identified in plenary discussions. Of the 5 groups, 4 (80%) did not include specific features for medical students in their designs. The main reason for this, the students stated, was that they did not want to be seen as an exclusive target group but rather as students in general. However, they implemented some aspects that are typical of students or people working in health care (eg, shift work). Especially, customizations addressing students' needs in general (eg, low income, high workload, and irregular schedule) were considered essential. Accordingly, it was important to the students that their app should be provided to university students free of cost. Most groups also offered a variety of ways to customize the app. For instance, push notifications could be scheduled to match users' preferences or be completely turned off. These customizations were believed to provide a more pleasant user experience and facilitate the daily use of the mHealth app, which was seen as a prerequisite for its success. Moreover, the students considered it important that their app should be easy and intuitive to use for a broad range of users, a reason for this being that medical students have a comprehensive schedule and are not willing to invest a lot of time getting acquainted with an mHealth app. All prototypes included some elements of gamification. In all, 2 aspects stood out because they were repeatedly highlighted by all the groups: data security and evidence base. The students in the workshop considered mental health to be a sensitive topic that should be treated confidentially. The students also seemed to have concerns regarding *big data*: they generally did not approve of companies storing or even selling their data and considered this to be a *no-go area* for an mHealth app. Furthermore, they stated that they would only trust an mHealth app that had been tested and approved by a trustworthy source (eg, their university) and was supported by scientific research.

The students also discussed strategies to improve the uptake of novel e–mental health services such as advertisements using testimonials, including potential negative effects of testimonials. They expressed skepticism regarding such testimonials, especially when they exclusively involve positive ratings. Rather, they preferred balanced reviews (including positive and negative aspects) by trusted sources. Taken together, this points to the need to include user target groups in the design process of mHealth apps to increase their acceptance and use.

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Textbox 2. Common themes among all groups during prototyping.

Common themes

- On the basis of scientific evidence
- Certification
- Transparent quality criteria
- Free of cost or cost reimbursement
- Personalization
- Gamification (limited and not too playful)
- Easy and intuitive handling
- Daily use or daily commitment (eg, reminders)

Case Illustrations: App Development

In this section, the hypothetical prototypes developed by 40% (2/5) of the groups will be presented as exemplary concepts. The 2 prototypes in this paper were chosen based on their visual clarity and comprehensive concept. All creative theoretical work and design samples belong to the students and cannot be used without their permission.

- *Moodly* (an mHealth app for depressive symptoms [early intervention]; Figures 1-7): a group consisting of 7 students (n=4, 57% were women, and n=3, 43% were men) created the app concept for *Moodly* for mild to moderate depressive symptoms. In Textbox 3, the app is described in the form it would have taken had it been programmed and implemented.

Textbox 3. App concept for Moodly.

***Moodly*: app concept**

- *Moodly* would be accessible as both mobile app and web-based program. The students stated that the goal of the app is to decrease depressive symptoms, impart positive impulses for the day (eg, recommendations for positive activities), and provide guidance to better deal with negative emotions and thoughts (eg, using relaxation exercises). Moreover, it aims to give users a daily structure, improve self-efficacy, and create awareness of their emotions and thoughts.
- The target group consists of not only medical students but also students in general who display depressive symptoms or are experiencing a mild depressive episode (ie, early intervention as the first step or additional support). Users are encouraged to seek professional support; the app informs them that it is not a substitute for treatment.
- The app includes elements of gamification, including personalization, reminders to use the diary, and motivating messages. To increase adherence and use in the long run, users can adapt the app design to their needs and preferences. They can use emojis, upload a picture, or include Graphics Interchange Format files and stickers when making a diary entry. Moreover, the app is structured in a specific order. When students complete a level, they receive a *level up* notification (progress and rewards).
- The students described the design as colorful and esthetic. Users can create a profile and chat and interact with other users. Furthermore, the app provides a variety of helpful videos and resources, for example, to deliver psychoeducation. Therapists and scientists will verify all content in the app. The students highlighted that the app is easy and intuitive to use.
- As the students were worried about people who use the app having an acute mental health crisis, an *emergency help* button is included in every screen (Figures 2-7). If users tap the button, a screen opens through which users can directly contact the German suicide prevention hotline or chat with a psychologist from the app itself (Figure 4). These psychologists are professionally trained in first-line psychotherapy approaches such as cognitive behavioral therapy.
- Before the app is launched in app stores, all students from Heinrich Heine University Düsseldorf would have the opportunity to test it. If they approve it, this can be extended to other universities. Finally, students could provide testimonials for the app in diverse app stores. The entire process would be monitored and assessed by scientists at Heinrich Heine University Düsseldorf.
- Another major concern highlighted by the group presenting *Moodly* was data security. *Moodly* would be strictly anonymous; only admins and therapists available on the app would have access to a user's email address in case of emergency (eg, suicidal thoughts). Terms of use would be communicated transparently and be easy to understand.
- The app should be used daily.

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Figure 1. Logo of the app *Moodly*.

Figure 2. Mock-up of the app *Moodly*: users are asked whether they want to answer questions to personalize the app.

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Figure 3. Mock-up of the app *Moodly*: menu and home screen.

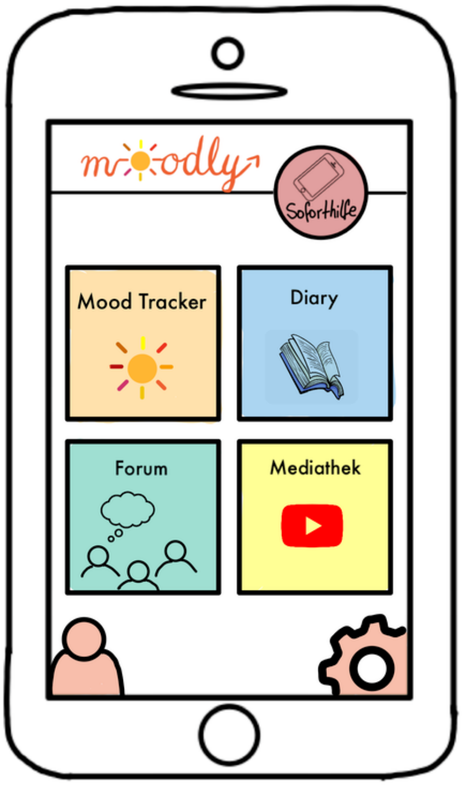

Figure 4. Mock-up of the app *Moodly*: emergency help screen.

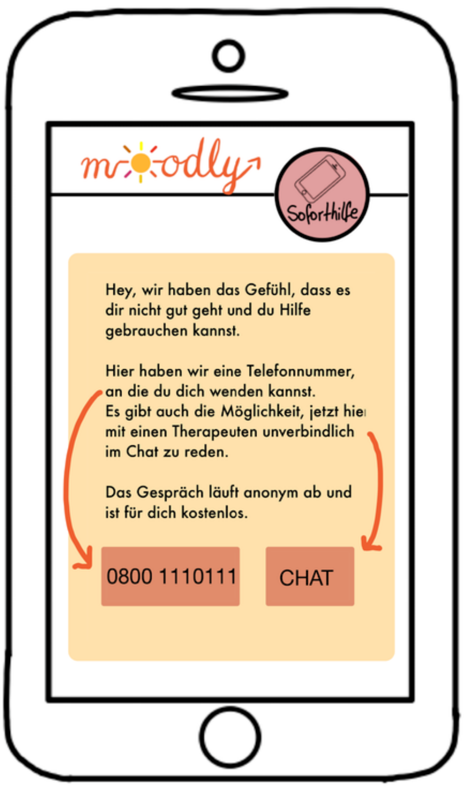

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Figure 5. Mock-up of the app *Moodly*: diary.

Figure 6. Mock-up of the app *Moodly*: mood rating.

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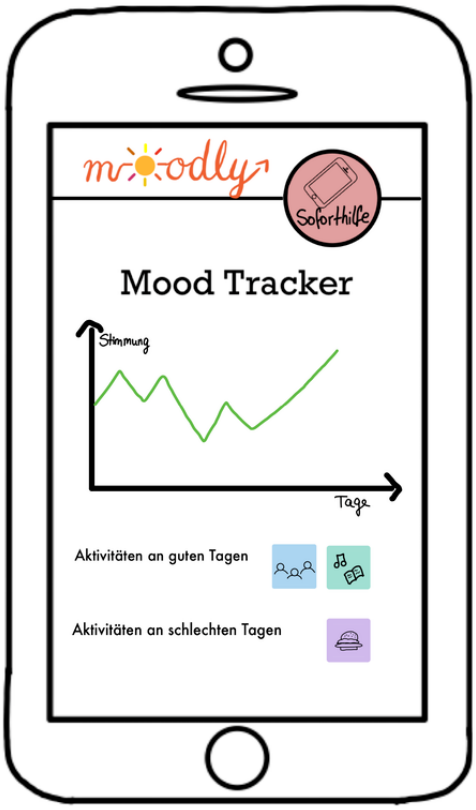
Figure 7. Mock-up of the app *Moodly*: mood tracker.



- *Dreamy Pug* (an mHealth app for insomnia; Figures 8-19): a group of 3 students (n=2, 67% were women, and n=1, 33% was a man) developed the concept for the insomnia app *Dreamy Pug*. In Textbox 4, the app is described in the form it would have taken had it been programmed and implemented.

Figure 8. Logo of the app *Dreamy Pug*.

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Textbox 4. App concept for Dreamy Pug.

***Dreamy Pug*: app concept**

- The students designed this mobile app for people with insomnia who want to improve their sleep quality.
- Before the first use, users can answer questions (eg, about their age; Figure 15) to receive tailored suggestions on sleep behavior.
- The app is not specially targeted at medical students but rather created for people working in shifts (eg, hospital staff) as they face additional challenges because of their irregular sleep schedule. The app is also suitable for students who often study and sleep in the same place (studio apartment) and face multiple distractions because of their extensive use of smartphones and other electronic devices.
- In case of severe insomnia, users receive an alert to seek help from a professional.
- *Dreamy Pug* aims to increase sleep duration and quality. Moreover, it offers psychoeducation to improve users' knowledge and understanding of insomnia and the lifestyle and health behavior factors that influence it. This includes exercises to help users fall asleep or for relaxation (eg, progressive muscle relaxation) as well as tips for better sleep hygiene and environment control. All exercises and tips in the app are based on scientific evidence and reflect guidelines from medical societies.
- The avatar *Dreamy the Pug* guides users through the app, explaining its functions. Handling and language of the app have been made as understandable as possible. The app monitors duration and quality of sleep. These data then help to personalize the app to users' needs and habits.
- Wearables can be connected to the app to improve the quality of sleep tracking. If a user wakes up during sleep, the app recognizes this and immediately offers them help to go back to sleep. In addition, the app can restrict the use of other apps during the time users want to sleep (eg, social media apps). The students stated from personal experience that when they use these apps during the night, going back to sleep becomes harder.
- Further personalization of the app is possible, such as the regulation of push notifications. The app has 3 main modes for night, morning, and day (Figures 11-13). Design and luminosity vary within these modes.
- The group that designed *Dreamy Pug* pointed out that it would be provided free of cost to students after it has been certified and tested in scientific trials.
- The app includes several elements of gamification. The mechanism behind points and rewards is positive reinforcement. If users sleep well, they gain points that they can use to unlock new characters (eg, *Sleepy Fox*) or new sets of blankets for *Dreamy the Pug*.
- Users can also track their progress (Figure 19). In this section, statistics on sleep duration are depicted.
- The app should be used on a daily basis to ensure a reliable sleep profile.

Figure 9. Mock-up of the app *Dreamy Pug*: storyboarding and first draft.

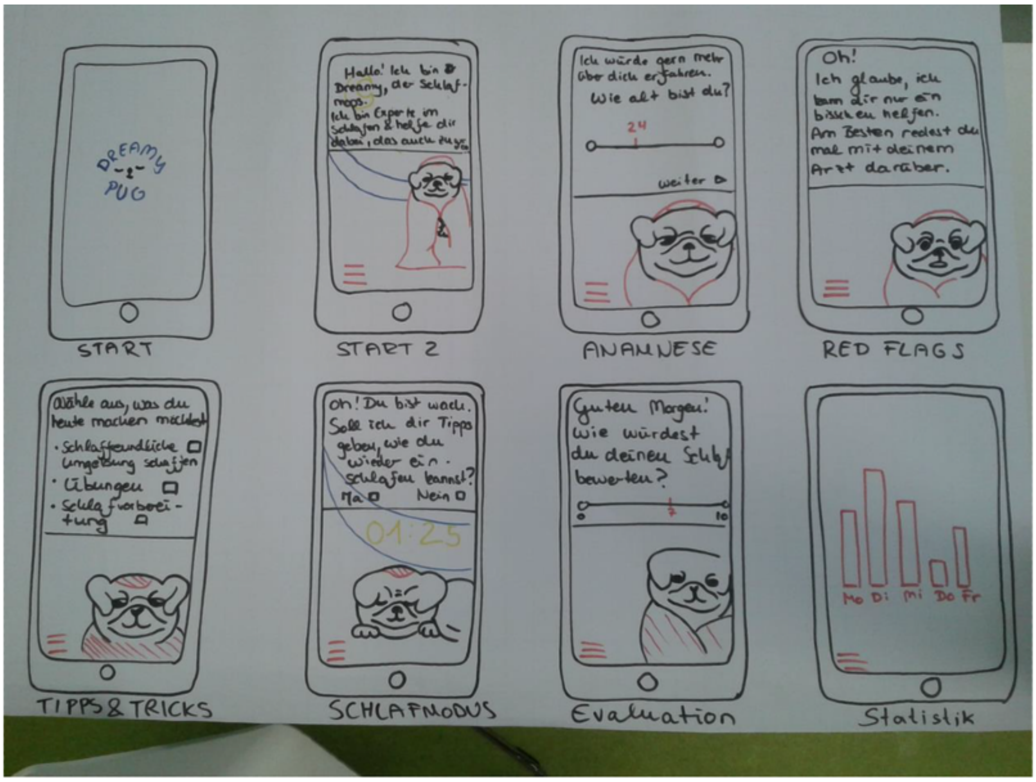

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Figure 10. Mock-up of the app *Dreamy Pug*: Dreamy the Pug, the avatar.

Figure 11. Mock-up of the app *Dreamy Pug*: Screen adapts to different times of the day (here: Night screen).

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Figure 12. Mock-up of the app *Dreamy Pug*: Screen adapts to different times of the day (here: Morning screen).

Figure 13. Mock-up of the app *Dreamy Pug*: Screen adapts to different times of the day (here: Evening screen).

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Figure 14. Mock-up of the app *Dreamy Pug*: welcome screen.

Figure 15. Mock-up of the app *Dreamy Pug*: assessment of personal data (here: age).

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Figure 16. Mock-up of the app *Dreamy Pug*: menu from which to choose different exercises.

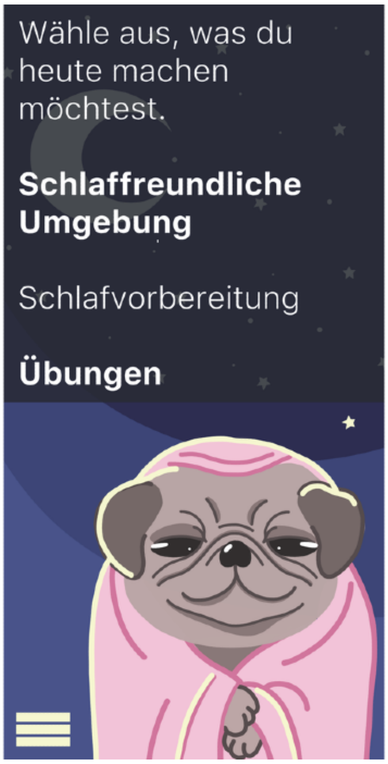

Figure 17. Mock-up of the app *Dreamy Pug*: nightly intervention after user woke up during sleep.

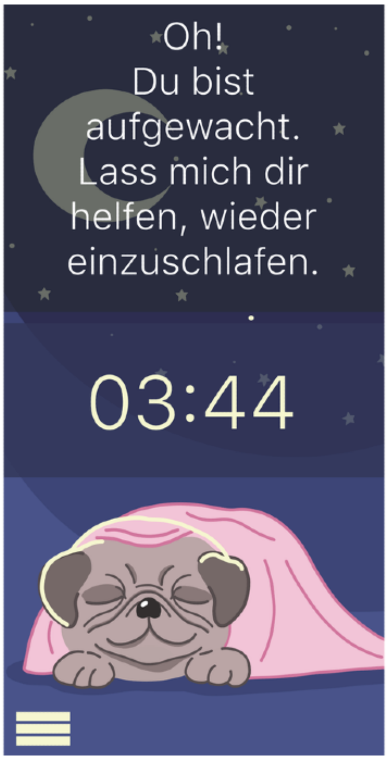

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Figure 18. Mock-up of the app *Dreamy Pug*: sleep rating.

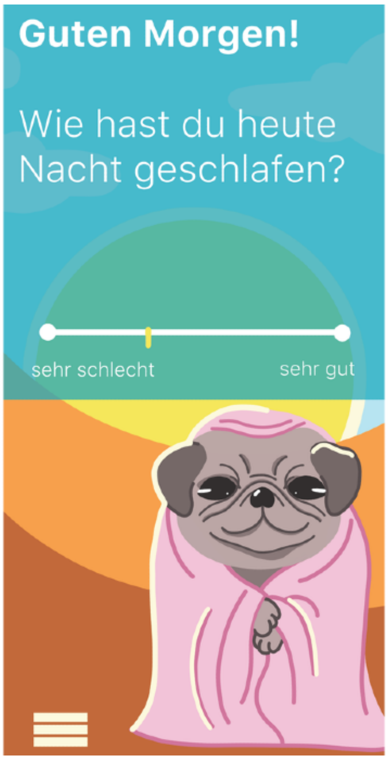

Figure 19. Mock-up of the app *Dreamy Pug*: sleep tracking.

Workshop Evaluation and Suggestions for Improvement

The feedback from participants upon workshop completion showed that, among other things, it was well-received. The students showed great interest in the presented contents, including the acquisition of knowledge about quality-approved e–mental health solutions. In addition, the students emphasized the benefits of involving potential users in app development. However, the face-to-face workshop was seen to be in need of improvement. The students requested more self-learning components and web-based tools as well as more opportunities to test e–mental health solutions. Moreover, they suggested including more group work, individual work, and interactions in terms of mutual exchange of ideas and exercises of practical relevance. By expanding the digital elective components, the

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elective course could also be better integrated into everyday life and thus increase the learning effect (self-directed learning and e-learning).

The feedback questionnaire suggests that most of the students were not familiar with e–mental health before the workshop (Table 2). Of the 26 students, 22 (85%) somewhat disagreed, disagreed, or strongly disagreed that they already knew a lot about the learning contents provided at the workshop (mean 2.38, SD 1.10; equals *somewhat disagree*). Of the 26 students, only 1 (4%) agreed that they were familiar with e–mental health before the workshop; 21 (81%) somewhat agreed, agreed, or strongly agreed that they had learned many new things (mean 4.58, SD 1.10; equals *agree*); and 17 (65%) somewhat agreed, agreed, or strongly agreed that they had learned valuable content for their future practice as physicians (mean 3.77, SD 1.24; equals *somewhat agree*).

Students suggested the following improvements in the free-text questions of the feedback questionnaire: learning more about existing apps, testing specific apps, and learning more about app design and technical implementation ("What is needed to create a good app?").

Table 2. Workshop evaluation (scale from 1=strongly disagree to 6=strongly agree).

Question	Values, mean (SD)	Values, median (IQR)
"Before the workshop, I already knew a lot about the topics covered in the workshop"	2.38 (1.10)	2 (1.25)
"I learned a lot of new things in the workshop"	4.58 (1.10)	4.5 (2)
"I have learned a lot of useful things for my profession"	3.77 (1.24)	4 (2)

Discussion

Principal Findings

The aim of this study is to describe an innovative concept for an educative workshop following a participatory co-design approach. Moreover, we wanted to present samples of medical students' prototypes and ideas for mHealth apps, highlighting their preferences and needs.

The co-design workshop was well-received by medical students. It created an environment that allowed participants to engage and be creative from both user and prospective health care provider perspective. The small groups ensured that all participants were able to engage in the design process, as suggested in previous research [40,41].

Moreover, the students provided insights into how mHealth apps can be designed to meet their needs: they agreed that it would be beneficial if the app considered challenges that are specific for shift workers and students in general. Throughout all groups, one of the main issues highlighted by participants was data security provided by their app. This finding fits into the international literature, where data protection concerns have been identified as a key barrier for the adoption of eHealth across various target groups [42].

Confidentiality was another related topic relevant for medical students, especially because many mental health apps do not fulfill this criterion [43,44]. This is interesting to note, considering that stigmatization of mental illness is still prevalent in the medical field, and especially students fear professional disadvantages from the disclosure of a mental health problem [2,45]. It is important that mHealth apps provided for medical students are approved by trustworthy sources such as the students' university [27]. Similarly, students perceived the app being tested in scientific trials and receiving certification for its effectiveness as an indicator of app quality. Furthermore, the students suggested that information regarding the evidence base, including references to randomized controlled trials, should be integrated into the app's description to support informed decisions. Further information on the provider or on data security should be included in the app's terms and conditions section.

In addition, the participants declared customizable elements, easy and flexible use, and daily commitment as essential during the presentation of their mHealth app prototypes. This is in line with the principles of persuasive design, which has also gained importance in the health informatics educational sector in recent years [46]. All groups included elements of gamification in their apps, which is in line with the determinant hedonic motivation in the UTAUT2 model [33] and aims to foster user engagement, motivation, and adherence [47]. Moreover, gamification might improve the learning process in health education [48].

However, the students were critical of parts of the lectures on mHealth apps because they had difficulty following them on an abstract level without an mHealth app for practical demonstration. This was due to the limited availability of freely accessible quality-approved mHealth apps, which has been acknowledged as a barrier in previous mHealth educational research with medical students [24]. Hence, future educational workshops should preselect suitable mHealth apps and provide them to students in the workshop.

Interestingly, the group discussions and prototypes developed in this workshop suggest that most medical students do not see an urgent need for mHealth apps directly targeted at medical students [27]. Only specific features for students (eg, low income, high workload, and exam-related distress) or people working in health care (eg, shift work) were proposed.

Several quality-approved, effective digital mental health interventions for students exist [5,49], but they are not well known or used by medical students. Therefore, the key challenge is to reach medical students. This could be achieved with targeted information or through specific channels (eg, student support groups and mentoring [49]). However, medical students may not be particularly interested in apps that are exclusively designed for them; rather, they might be interested in apps that are designed for students in general. Medical students are at

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high risk for certain mental illnesses [30,50,51], and their lack of help-seeking behavior is of great concern [52]. Thus, it is important to increase the adoption of psychological services, including early interventions, for example, by offering mental health apps. Overall, medical students in our workshops preferred to emphasize similarities rather than diverging factors between them and other student groups. However, to be able to answer the question of whether mHealth apps targeted at medical students are desired, a more representative sample is required.

Another goal of the workshop was knowledge acquisition and transfer in terms of competence-based collaborative learning (ie, application of acquired knowledge).

Overall, it is striking that only 31% (8/26) of the students agreed or strongly agreed that they had learned anything they consider valuable for their future practice. It is possible that the students did not deem eHealth relevant for their profession, which hints at the need for more education to familiarize students with eHealth. Generally, this finding can be seen in light of the period when the workshop was conducted, namely in early March 2020, 1 week before the first lockdown due to the COVID-19 pandemic in Germany. The pandemic was an unexpected driver for the transition of telemedicine into health care, especially the spread of videoconferencing consultations and also e–mental health services [53].

Furthermore, it is possible that some contents such as the demonstration of the UTAUT2 model [33] were too theoretical and not directly transferrable to clinical practice. On the basis of the students' feedback, we have revised the workshop contents and format to integrate more practically relevant topics (eg, the concrete procedure for the prescription of apps and legal issues) and to tailor the workshop to individual needs and preferences (see *Lessons Learned* section). Overall, more efforts are needed to implement suitable educational workshops on the digitalization of health care in the medical curriculum, especially considering that increasingly more medical students recognize the relevance of the topic for their future profession [54,55].

Lessons Learned

The suggestions received at this pilot workshop have been transferred to a novel e-learning participatory design workshop with medical students. It was conducted for the first time in the 2021 summer semester (e–mental health literacy as an elective subject, with support of the Medical Faculty Quality Funds for innovative educational projects). A novelty of the new e-learning workshop on e–mental health and mHealth for medical students is that it offers an extensive e-learning module on the quality criteria of mHealth apps as well as new ways of implementing remote group work (under continuous guidance by the team of educators), and their integration into routine care, design thinking, and gamification. This helps to systematically guide small groups of medical students through the design of a prototype mHealth app, alongside engaging sessions and continuous tailored feedback. The platforms used are ILIAS (an open-source digital learning platform for asynchronous self-directed learning), Webex (Cisco Systems, Inc), and Microsoft Teams (videoconference-based *live* synchronous meetings and collaborative learning), as well as free prototyping software. On the basis of the students' feedback, the workshop will be iteratively refined using participatory design approaches.

Thus, the subsequent workshop included new educational content of more practical relevance for medical students, such as the prescription of apps. Moreover, the switch to e-learning seems to have facilitated knowledge acquisition significantly: the second workshop was evaluated more positively compared with the pilot workshop, and knowledge acquisition was rated consistently as *high*. Future workshops could also include objective tests regarding the improvement of eHealth literacy, for example, through a quiz at the start and the end of the workshop (pre–post design). However, for us, it was primarily important to learn whether students deem the workshops to be valuable as an educational tool and which aspects need to be adopted for future workshops.

Upon completion of the quality-improvement project, the participatory workshop will be implemented as a standard elective subject in the medical curriculum at HHU. The curriculum will likely be extended to other fields in eHealth as well, such as digital health for chronic conditions. Moreover, a collaboration with the university's computer science department is planned that could offer the opportunity to translate medical students' ideas into actual mHealth apps. This case study lays the foundation for these ambitions by exploring medical students' perspective in detail, providing concept sketches, and initiating communication channels.

Limitations

The exploratory nature of our case report entails several limitations that must be considered. First, our results concerning medical students' ideas and preferences for mHealth apps are not conclusively generalizable to the entire medical student population. Rather, this case study offers subjective insights into participatory workshops for educational purposes from the educators' perspective.

A second concern related to generalizability is that participants chose the workshop as an elective course. Thus, there might be a self-selection bias if especially students familiar with, or interested in, mHealth attended the workshop. Students with no interest in mHealth could have had other ideas or preferences compared with those of the workshop participants. However, the students indicated low familiarity with eHealth, and many chose the workshop as an elective course because it was held on 5 consecutive days during the semester holidays.

Third, all participants were regular smartphone users as well as digital natives and therefore widely familiar with smartphone apps. It became evident on different occasions (eg, in group discussions and feedback rounds) that they had already formed critical opinions on related topics (eg, *big data*) before the workshop. This might be why they highlighted the importance of data security.

Furthermore, it is likely that the different lectures, exercises, and tasks throughout the workshop (eg, creating avatars and personas as well as learning about mHealth guidelines) influenced the students' prototypes. However, they only included elements that they perceived as useful for their prototype (eg, no avatar in *Moodly*).

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Finally, the workshop was conducted in Germany where digital health is not yet a mandatory or widespread part of medical education [22]. However, it is important to note that medical schools in many countries worldwide have already recognized the urgent need to implement eHealth in the curriculum. The rate of progress in the digitalization of health care has increased, especially since 2020, for instance, in Switzerland [56]. A next step for German medical schools would be to integrate digital competencies in the NKLM (*Nationaler Kompetenzbasierter Lernzielkatalog Medizin* or National Competence-Based Learning Goal Catalog for Medicine) accordingly [22,57].

Implications and Recommendations

For Researchers

Researchers might consider the following implications and recommendations:

- Develop an empirical and theory-led guide for best practice through continuous evaluation of medical students' preferences and needs using both qualitative and quantitative research methods.
- Define and test outcomes of the learning success by combining subjective and objective measures based on digital health technology literacy frameworks [58]. However, note that there is a lack of randomized controlled trials in the field because workshops within elective subjects pose organizational and ethical challenges for this particular study design [59].
- Enable the cocreation of educational content using participatory research approaches (eg, person-based approach [60]).

For Lecturers

Lecturers might consider the following implications and recommendations:

- Define a set of clear competencies and learning goals that should be obtained through the workshop [55].
- Provide personalized and interactive digital learning platforms in line with recent trends [55].
- Select and use novel educational tools and web-based platforms such as Psy-Q [61].
- Learn how to create apps—easy and intuitive software tools to build initial apps exist (eg, iBuildApp [62]).
- Encourage the collaboration of physicians and informatics experts as lecturers, for example, as shown in the DigiWissMed project in Germany [63].
- Offer trainings in digital health for medical educators.

For Medical Schools

Medical schools might consider the following implications and recommendations:

- Note that in Germany, most eHealth-related topics are taught within elective subjects, and the number of such courses is very limited [22]. Usually, these existing eHealth courses in Germany do not consider mental health as a relevant topic for medical students as potential users and future physicians. Hence, there is a need not only for eHealth education in general, but also for digital mental health in particular. Surveys could help to determine the needs and preferences of medical students regarding the implementation of eHealth in the curriculum.
- Note that not all medical students may be interested in eHealth or in creating their own apps in the same way. Thus, basic knowledge on eHealth could be implemented in the standard curriculum, whereas more advanced or in-depth courses could continue to be part of the elective curriculum [64].

Conclusions

Overall, the participatory workshop on e–mental health was well-received by medical students. Thus, it seems to be a feasible approach that can be used as a starting point for future educational activities with medical students. Moreover, the medical students had a clear vision for their ideal mHealth apps after being informed about key quality criteria and persuasive design features. As medical students are both potential users and future health care providers, the adoption of mHealth education into the medical curriculum should be considered.

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Conflicts of Interest

None declared.

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Abbreviations

HHU: Heinrich Heine University Düsseldorf
mHealth: mobile health

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NKLM: Nationaler Kompetenzbasierter Lernzielkatalog Medizin
UTAUT2: Unified Theory of Acceptance and Use of Technology, extended version

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Original Paper

An Online International Collaborative Learning Program During the COVID-19 Pandemic for Nursing Students: Mixed Methods Study

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Abstract

Background: Given the limitations imposed by the COVID-19 pandemic, a better understanding of how nursing programs around the globe have implemented distance education methods and related initiatives to provide international collaborative learning opportunities as well as complementary aspects of practical education would be constructive for nursing students. It is expected that international collaboratives through web-based communication will continue to be increasingly utilized after the pandemic; therefore, it is time to discuss the effects and direction of these developments.

Objective: We aimed to examine the impact of an online international collaborative learning program on prelicensure nursing students' international and global competencies in South Korea.

Methods: We conducted a mixed methods study (web-based surveys and focus group interviews). A total of 15 students participated in the study. The surveys were used to examine changes in participants' global leadership competencies, and the focus group interviews were used to evaluate the program's effectiveness and to identify opportunities for improvement. The online international collaborative program consisted of 7 synchronous web-based classroom sessions. Each session ran for 60 to 90 minutes. Faculty experts and nurses working in the United States discussed various topics with students, such as nursing education in the United States and evidence-based teaching and learning. The students gave presentations on the South Korean nursing education system. Data were analyzed with descriptive statistics, the Mann-Whitney U test, and content analysis methods.

Results: Participants reported improvement in their global leadership competencies. Four main categories emerged from analysis of the focus interviews: (1) realistic applicability, (2) clarification, (3) expansion of perspectives, and (4) initiative.

Conclusions: The online international collaborative learning program had a positive impact on the development of students' international competencies. The findings support the further development of international exchange programs through web-based meetings in the postpandemic era.

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KEYWORDS

COVID-19; distance education; global competencies; nursing students; program evaluation; synchronous virtual classroom; video conferencing

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Introduction

Since the first COVID-19 infection was diagnosed in South Korea, rapid changes designed to contain the spread of the virus have affected all aspects of society [1]. The implementation of social distancing, isolation, and quarantines have forced people to work, learn, teach, and pursue activities of daily life while avoiding direct face-to-face contact as much as possible [2,3]. The shift away from direct personal engagement has been particularly evident in education as learning methods have expanded to include approaches conducted online and remotely [2,3]. Distance education has transitioned from being considered a learning method with future potential to becoming a common and accepted response to a global need [4-6]. Universities are embracing this trend toward distance learning by striving to strengthen online teaching expertise and learning capabilities and by progressing projects to develop a web-based education infrastructure necessary for the contactless era [7].

University international exchange programs have been especially affected by the COVID-19 pandemic [7]. Whereas international exchanges formerly consisted primarily of on-site in-person interactions, the prolonged COVID-19 outbreak has restricted movement between countries, making it difficult to develop global competencies through in-person visits and necessitating alternative means of conducting exchanges, such as videoconferences [7]. Although exchange programs have faced challenges to participation due to cost issues [8] and time constraints [9,10], strengthening the global competencies of nursing students remains of vital importance. The American Association of Colleges of Nursing [11] maintains that a nursing curriculum that reflects cultural competency factors contributes to an understanding of patient values and preferences as well as respect for and positive attention to patient needs.

Attempts to promote and enhance global competencies via international exchange have taken various forms. The Korean Accreditation Board of Nursing Education [12] has added awareness of domestic and international health policy changes to learning outcomes that lead to Nursing Education Accreditation, an addition reflected in curriculum revisions. The new recommendations have led South Korean nursing colleges to incorporate international collaborative learning activities into curriculum, including special lectures about or participation in diverse program activities [13], visits to low-income countries to observe health education practices [9], or training at advanced education institutions [10].

Despite the importance of international exchange programs in developing nursing students' global competencies, there has been insufficient research to evaluate program content and learning demands. In a study [8] that compared the need for international exchange in nursing students from the United States, Vietnam, and South Korea, those from South Korea showed the high willingness to learn about international employment trends and the effects of the movement of health care personnel. Furthermore, nursing educators in Korea who were surveyed stressed that nursing students needed preparation to respond to the globalization of health and health care, and that global health competencies should be integrated into the undergraduate nursing curriculum [14]. Previous research suggests that international exchange programs should (1) allow students to obtain answers to their questions about international nursing activities through direct communication with nurses who are currently working in the international arena, and (2) set specific goals for nursing students who desire to become global nurses.

Global nursing competencies are reinforced as students from different nursing education systems exchange information and ideas, compare and weigh differences and similarities in nursing curricula, broaden their perspectives, and develop more mature critical thinking abilities [15]. Given the limitations imposed by the COVID-19 pandemic, a better understanding of how nursing education programs around the globe have implemented distance education methods and related initiatives to provide international collaboratives as well as complementary aspects of practical education would be constructive. Although the effects of online international exchange programs have not yet been reported, it is expected that international collaboratives through web-based communication will continue to be increasingly utilized after the COVID-19 pandemic; therefore, it is time to discuss the effects and direction of these developments. We aimed to analyze the effects of changes in educational delivery methods due to the COVID-19 pandemic on prelicensure nursing students participating in online international collaborative learning programs.

Methods

Study Aim and Design

A mixed method design was used in this study. We used quantitative research methods to evaluate the program quality of online international collaborative learning programs and the global leadership competencies of nursing student participants; we used qualitative research methods (focus group interviews) to explore the impact of participating in the program.

Participants

Undergraduate students applied to and participated in the online international collaborative learning program led by the Office of International Affairs at Ewha Womans University. Students who completed the program with at least 70% attendance were eligible to be included in the study. All 16 students were eligible to participate and were offered the opportunity to participate in the study. Of them, 15 agreed to participate in the study.

Instrument

Global Leadership Competencies

Global leadership is a competency that positively influences the thoughts, attitudes, and behaviors of stakeholders beyond the national, cultural, and linguistic differences based on open-mindedness and diversity for organizational growth [16,17]. To measure the global leadership competencies of undergraduate nursing students, we used a previously developed tool [16], based on 5 global leadership competencies [17], that consists of 18 questions comprising 5 subthemes: global mind (3 questions), open attitude toward diversity (4 questions), global network (3 questions), performance improvement skills (3

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questions), and basic attitude competency (4 questions). The tool was modified to evaluate competency improvement for each question, which was assessed with a 5-point Likert scale ranging from 0 (not improved) to 4 (improved); the higher the score, the higher global leadership competency improvement compared to that before participation in the program. When this tool was developed, factor analysis was conducted to verify its validity; the construct validity was verified by explaining 63% of the total items; in subthemes, Cronbach α=.68-.78 [16]. In this study (all items), Cronbach α=.98.

Quality of Program

We used the Student Evaluation of Educational Quality [18] to evaluate university lectures, which consists of 35 evaluation items in 9 themes (Cronbach α=.88-.97): (1) learning and value of lectures, (2) enthusiasm of instructors, (3) structures of lectures, (4) interaction between groups, (5) personal relationship formation, (6) scope of learning content, (7) tests, (8) assignments, and (9) levels of burden and difficulty. We selected 10 items to evaluate the value of learning, instructors, and group activities; each item was assessed with a 5-point Likert scale ranging from 1 (not at all) to 5 (very much). A higher point indicated a better evaluation of the educational program. In this study (all items), Cronbach α=.89.

Development of the Virtual International Collaborative Learning Program

The Office of International Affairs at Ewha Womans University funds an international exchange program each semester; a lead professor plans, supervises, and facilitates the entire program, and students receive a small scholarship upon completion of the program. However, due to the spread of COVID-19, the program was conducted using a videoconferencing platform (Zoom, Zoom Inc). The program was operated by the lead professor in collaboration with a nursing professor at Duke University in the United States; the program consisted of 7 synchronous sessions (running 60 to 90 minutes per session) presented from November 17 to December 22, 2020 (Figure 1). The first session provided an overall program orientation—introduced the program, formed groups, and selected group activity topics. In consideration of the students' varying levels of clinical practice experience, they were placed into 1 of 5 groups (of 3 to 5 students); each group prepared presentation materials 5 times through group activities. Students were expected to submit individual activity reports that consisted of a summary of the day’s program, details of activities, and questions to evaluate the program. In the second and third sessions, students attended special lectures by a professor in the United States on the current status of and latest trends in US nursing education. The students gave presentations on the South Korean nursing education system, analyzing and comparing nursing education in the United States with that in South Korea. In the fourth session, students had a colloquium with a registered nurse and an advanced practice registered nurse in the United States about the role of nurses and nurse specialists and their working experiences in the United States, with a question-and-answer session, and discussed the role of nurses in different medical environments. In the fifth session, the characteristics of clinical practice education in the United States and South Korea were compared and critically analyzed by exchanging stories with undergraduate students in the nursing colleges in the United States. In the sixth session, students had a forum with a professor and discussed the postpandemic future of nursing education as well as their personal plans and goals. The seventh session consisted of a meeting to evaluate the program.

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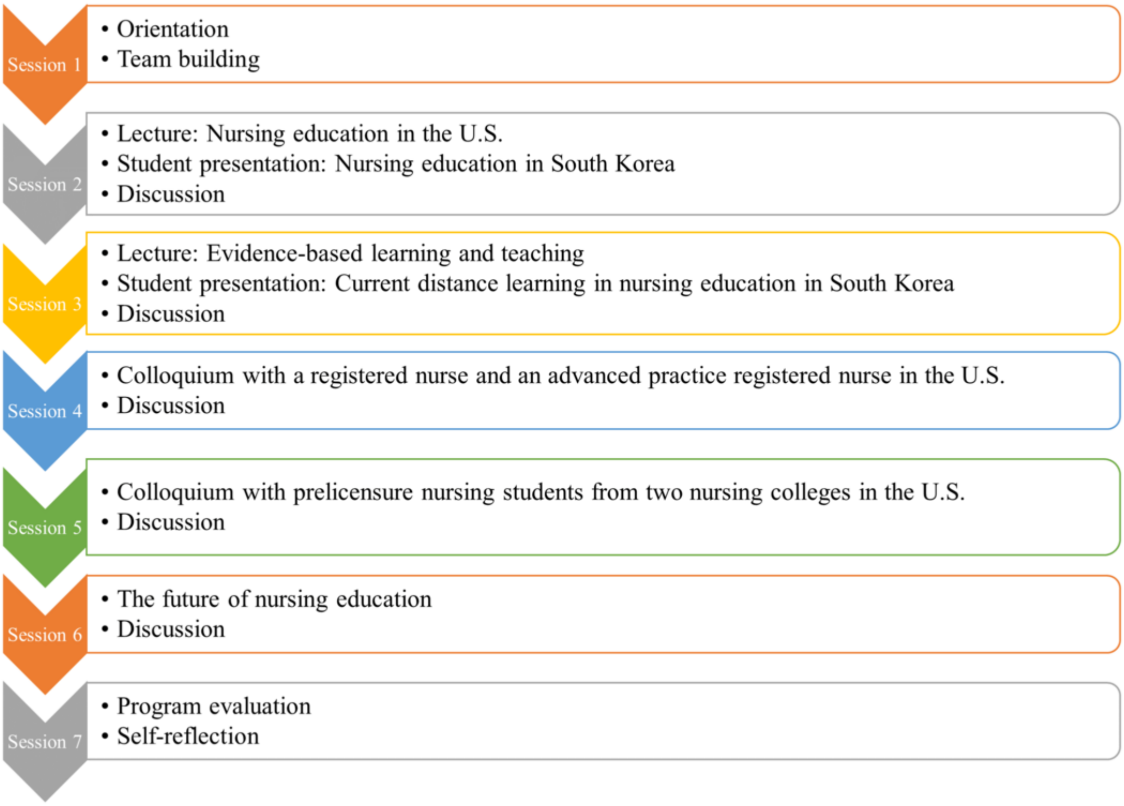
Figure 1. Online international collaborative learning program.



Data Collection

Data were collected from December 23 to 29, 2020 from college-level nursing students who had completed the program. Quantitative data were collected through a web-based survey using Google Forms, and respondents were asked to complete the survey after providing consent to participate in the study. Focus group interviews were conducted via Zoom by a researcher who was not involved in supervising the educational program. Although the number of participants in a focus group interview varies depending on the literature, it has been found that 7 to 10 participants per group are desirable [19]; thus, 2 groups of 7 or 8 participants (for a total of 15 participants) were formed for 1-hour interview sessions. The interview constituted the relationship-building stage and began with participants introducing themselves to one another and having a casual conversation to break the ice; next students were asked to respond to a wide range of questions or requests, such as "Tell me how you felt while participating in the program?" Participants were encouraged to speak freely about their experiences and to listen to others' stories and were prompted to answer further questions: "How have you changed after the participation in this program? What kinds of difficulties did you experience during the program? How did this program affect your major capability? What types and methods of education do you think would be more effective? Can you tell us how this program can be more improved?"

During the interview, the interviewer summarized answers to the questions, asking whether the summary was accurate and if anything had been missed. Data collection through interviews continued until the meaning of experiences and subject matter reached theoretical saturation [20]. After each focus group interview, the researcher who had conducted the interview watched and listened to the interview session several times, in order to transcribe the contents as exactly as possible, and confirmed the meaning by reading the transcribed text. The finished transcription was reviewed by a lead professor to ensure accuracy.

Data Analysis

Quantitative Analysis

Quantitative data were analyzed using SPSS statistical software (version 23.0; IBM Corp). The general characteristics of participants were represented by frequency and percentage or mean and standard deviation. Global leadership competency improvement (on a 72 point-scale) and program quality were represented by mean and standard deviation. Global leadership competency improvement and participant characteristics were analyzed using a nonparametric method (Mann-Whitney *U* test).

Qualitative Analysis

The focus group interviews were analyzed using a qualitative content analysis method [21]. Researchers repeatedly read the transcribed data to understand the meaning of participants' thoughts and reflections about the effectiveness of the program. Each researcher read the data and extracted meaningful phrases and sentences containing key concepts. They read the extracted main text, recorded abbreviated semantic units to create proper titles, grouped similar words and compared their differences, and then extracted more abstract categories after discussion with the other researchers. After returning to the original data, they analyzed the transcripts as a whole to confirm the

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credibility of the category. The research results were shown to all study participants, who confirmed that their experiences in the program were well reflected.

Rigor of Research

We attempted to ensure the quality of research in terms of credibility, applicability, consistency, and neutrality, which are suggested criteria for evaluating the rigor of research [22]. As co-researchers reviewed and analyzed the data collaboratively, they evaluated and discussed whether the participants' statements had been converted into appropriate academic terms. In pursuit of credibility, during the integration and analysis of the data, they returned to the participants' original statements, reviewing whether the analysis results and the interview contents were consistent. For the confirmation of applicability, they shared the research results with a nursing professor with experience in qualitative research who had not participated in this study. During the process, the co-researchers fully understood the data analysis methods and maintained consistency. To ensure neutrality, a researcher who was not in charge of this program conducted interviews with participants, and the co-researchers continuously confirmed and discussed the interview narratives to prevent researchers' experiences and emotions from influencing the analysis.

Ethical Considerations

This study was conducted after obtaining approval from the institutional review board of Ewha Womans University (202012-0009-01). Participants were allowed to voluntarily access the web-based survey link. At the beginning of the survey, we provided instructions on the purpose of the study, contents, procedures, audiorecording for the interviews, anonymity of the data, and the right to withdraw participation at any time; after that, informed consent was obtained when the user clicked to indicated whether or not they agreed to participate in the study. Confidentiality and anonymity were maintained during data collection and analysis; personal information was not revealed when recorded data were transcribed. Collected data will be discarded after being stored for 3 years.

Results

Participant Characteristics

Of the 15 students who agreed to participate, the data from 14 participants were used for quantitative data analysis; data were omitted from 1 participant due to a missing response on the questionnaire. All participants were female (Table 1).

Table 1. Participant characteristics.

Characteristic	Value (n=14)
Age (years), mean (SD)	22.5 (1.16)
Gender, n (%)	
Male	0 (0)
Female	14 (100)
Level, n (%)	
Sophomore (2nd year)	3 (21)
Senior (4th year)	11 (79)
Reasons for program participation, n (%)[a]	
Acquire new knowledge	6 (21)
Personal achievement	11 (39)
Cultural contact	6 (21)
Intellectual curiosity	5 (18)
Previous study abroad program participation, n (%)	
No	6 (43)
Yes	8 (57)
If *Yes*, length of study abroad program experience (days), n	
≤5	3
6-9	1
≥10	4

[a]Multiple answers were possible.

Global Leadership Competencies

Mean improvement of global leadership competencies was 51.1 (SD 17.9) (Table 2). The most improved subtheme was *open attitude toward diversity*, which increased by a mean of 12.7 (SD 3.9 points) (on a possible range of 0 to 16 points) compared to the preprogram period. Analysis of the relationship between the characteristics of the participants and improvement in global

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leadership competencies showed no significant difference (*P*=.39) for second- or fourth-year students. There was a statistically significant difference in the subtheme *performance improvement skills* in improvement in global leadership competencies, depending on whether or not the participants participated in face-to-face international exchange programs before (*z*=2.08, *P*=.04).

Table 2. Improvement of global leadership competencies.

Theme and subtheme	Score, mean (SD)	Undergraduate level				Experience in international exchange programs			
	All (n=14)	Sophomore (n=3)	Senior (n=11)	*z* score	*P* value	Yes (n=8)	No (n=6)	*z* score	*P* value
Global leadership competencies	51.1 (17.9)	45.0 (17.1)	52.7 (15.6)	0.86	.39	57.9 (15.1)	42.0 (18.4)	1.81	.07
Global mind	8.5 (2.4)	8.0 (1.7)	8.6 (2.6)	0.45	.63	9.4 (2.1)	7.3 (2.4)	1.45	.15
Open mind to diversity	12.7 (3.9)	12.3 (3.5)	12.8 (4.2)	0.47	.64	14.0 (2.6)	11.0 (5.0)	1.44	.15
Global network	10.4 (4.7)	9.0 (5.3)	12.8 (4.2)	0.71	.48	11.6 (4.6)	8.7 (4.6)	1.31	.19
Performance improvement skills	7.9 (3.6)	6.0 (2.7)	8.4 (3.8)	1.18	.24	9.6 (3.0)	5.5 (3.1)	2.08	.04
Basic behavioral competency	11.6 (4.1)	9.7 (4.2)	12.2 (4.1)	1.02	.31	13.3 (3.7)	9.5 (4.0)	1.82	.07

Quality of the International Collaborative Learning Program

The mean program quality score was 48.1 points (SD 3.1) (Table 3); among the subitems, clear explanations by faculty, consistency with the program purpose, and instructor friendliness to students showed the highest record with an average of 4.9 points (SD 0.3).

Table 3. Student evaluation of program quality.

Program quality items	Mean (SD)
1. Program was intellectually challenging and stimulating.	4.6 (0.6)
2. Learned something considered to be valuable.	4.7 (0.5)
3. The instructor was dynamic and energetic in conducting the program.	4.9 (0.4)
4. The instructor’s explanations were clear.	4.9 (0.3)
5. The learning objectives were in line with the course content.	4.9 (0.3)
6. Students were encouraged to participate in discussions.	4.7 (0.6)
7. Students were encouraged to ask questions and were given meaningful answers.	4.8 (0.4)
8. Students were invited to share ideas and knowledge.	4.8 (0.4)
9. The instructor was friendly towards all students as individuals.	4.9 (0.3)
10. Feedback on group presentation was valuable.	4.9 (0.4)

Content Analysis of Focus Group Interviews

Content analysis revealed 14 subcategories in the categories *realistic applicability*, *clarification*, *expansion of perspectives*, and *initiative* (Table 4).

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Table 4. Content analysis of students' experience in the program.

Categories and subcategories	Example statements
Realistic applicability	
Obtaining answers to realistic questions	"From the standpoint of students, I could learn directly about how the practice was being conducted there [in the US], and I think it was a very good opportunity for comparative studies because I could listen to firsthand experiences of the treatment of nurses there."
	"I think it was nice to be able to ask questions about realistic concern[s] such as salary and what it is like living there as a nurse."
Listening to vivid experiences of clinical and practice sites	"I think it was good to be able to hear stories from the standpoint of nurses who are currently working or are students there [in the US]."
	"I think I got a lot of information because I was able to hear directly what my seniors said, and it was great to feel motivated and comfortable."
	"The contents that the professor explained felt more vivid coming from the perspective of the students."
Bridging the difference between direct and indirect experiences	"I have heard a lot of stories about the nursing environment in the US on the internet. Even though I have heard stories from across the globe, it felt very new hearing stories directly from the people in question."
	"I thought that there would be many things that would be a little different from the practice in Germany and that it would be hard to absorb the practice fully due to language barriers. But this time was comparatively smoother as it was English-speaking."
Clarification	
Demystifying vague aspects of practical problems	"I think the vague fear of the real problem I was concerned about has disappeared to an extent."
	"Rather than vaguely thinking about working in the US or abroad, it was nice to be able to think about the process and the real problems that come from it."
Clarifying vague aspects of careers	"In the past, I was only vaguely thinking about working abroad and obtaining very general information about the job of a nurse abroad. However, through this program, I was able to learn, in great detail, what the basis of going abroad should be and what is really needed for it, which has positively changed my attitude toward going abroad."
	"I thought it was very helpful because I was motivated a lot, and it seemed like I was stepping closer to something I had just thought vaguely about."
	"I was able to solidify my goals a little more, and although they are not perfect, I was able to focus on my future plans."
Solving queries through Q&A	"It was nice to have a lot of time to ask questions to satisfy my usual curiosity. I think it was a good opportunity to learn a lot."
	"Being a nurse in the US felt very obscure, but this has helped me feel more hopeful."
Addressing various topics as well as the work aspects of being a nurse	"I believe that learning about real-life issues regarding racism and how to deal with it, in addition to the actual job as a nurse, is a part of education, and this is helpful in that sense."
Expansion of perspectives	
Approaching the problem from a self-centered to system-centered perspective	"I also practiced at a university hospital for two years, and I never thought that it was natural for me to learn because this is a teaching hospital. I did not think that the nurses, the patients, or even the department head thought that way, but I was jealous that the American students were able to practice with that mindset. However, knowing that this is a systemic issue, I thought it would be good if it could be improved in Korea as well."
Broadening of international perspectives	"It was very nice to hear about the American system because I was always interested in it but never had the chance to hear about it around me."
	"It was nice that the professors and students from the US and Korea each gave presentations; so I could think about the commonalities and differences. It was also nice to broaden my perspective by meeting the other seniors who are in clinics."
Widening of career vision	"Originally, I was thinking of working in a clinic or preparing to work in public service in Korea, but this has helped me expand my vision and also consider being a nurse in the US."
	"I also liked being able to hear more practical stories, and frankly, I had little thought of being a nurse in the US, but listening to these stories made me feel more interested and like I have a wider choice of options."
	"I had dismissed my thoughts for a while because I was worried about getting a job at a Korean hospital after graduating, but it was nice to have a broader vision because of this opportunity."

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Categories and subcategories	Example statements
Expanding relationships through collaborative learning	"It was nice to be able to interact with people who work in the clinic or with students attending school there."
	"It seemed like a very good program overall as I was able to interact with many teachers."
	"First of all, I think it was a very meaningful time because I could ask questions about nursing education and the system in the US while interacting with professors, nurse, advanced practitioner registered nurse, and other nursing students from the US."
	"I think it was a meaningful opportunity to be able to communicate with people who are working in the US from whom there is a physical distance otherwise and be able to have my questions answered."
Initiative	
Positive changes in job perception and perspective	"I was able to be more open-minded. I was a little skeptical about the attitude of the people around me in the job as a nurse, but learning that this may be because of cultural and environmental differences has made me more hopeful."
Realizing the need for holistic nursing	"The most meaningful part for me was that it made me think about the nature of nursing. I think it was nice to be able to think about holistic nursing once more while listening to experiences of nursing in the US."
Changing to a positive attitude for the development of nursing	"Interacting with the American students has made me think that I should make a more active effort to develop nursing skills. I think I will be more proactive in thinking about and acting on problems in the future."
	"I think there are thoughts and cultures exclusive to nurses in Korea; so even if I went to the US to study and experience their culture, I think I would like to come back to Korea to make changes in better directions."
	"I also thought that I wanted to change the image and status of Korean nurses.
	"It was a meaningful time to think about what needs to be developed in Korea while interacting with the nurses and students."

Discussion

Principal Findings

We sought to evaluate the effectiveness of an online international collaborative program for nursing students by assessing global leadership competencies and program quality. Participants' global leadership competencies improved compared to before their participation in the program, and improvement in *openness to diversity* was particularly high among the subthemes. The findings are in line with those of other studies on face-to-face programs, for example, international exchange programs for nursing college students in Vietnam and South Korea consisting of lectures and visits to local hospitals and nursing education institutions contributed to developing global leadership competencies, understanding cultural diversity, and keeping an open mind [13]. Similarly, a short-term program abroad to increase global health competencies significantly raised nursing students' global leadership competencies [9,23] led to increased open-mindedness toward other people and cultures (the most remarkable change in competencies based on analysis of daily records) [9]. The program included presentations on the US nursing system and group presentations on the South Korean nursing system; students had opportunities to discern differences in health care and clinical practice systems through group discussions and question and answer sessions. The findings of our study indicate that such factors enabled them to accept and have more respect for diversity. Furthermore, our study confirmed that collaborative learning conducted online in lieu of field visits helped students improve their global leadership by allowing them to hear experiences described directly by field nurses and other nursing school undergraduate students.

There was no significant difference in improvement in global leadership competencies between students who had participated in face-to-face international exchange programs before and those who had not (P=.07). This is consistent with the findings of a previous study [24] in which students with participation experiences showed higher global leadership than those without such experiences, but the difference was not statistically significant. In our study, improvement in *performance improvement skills* in global leadership competencies was significantly higher (P=.04) for students with international exchange program participation experiences than that for students without these experiences. In this study, performance improvement skill was described as the capability to set organizational goals and utilize necessary information and resources to achieve results. Students with experiences showed more improvement due to synergistic effects of knowledge and information newly acquired through this program combined with knowledge and experiences acquired through previous international collaborative activities. Given these results, it seems necessary to continue to develop and implement similar international programs that can cultivate global competencies in nursing students; however, because this was a single-group postdesign study, quasi-experimental studies are needed to verify the effects of improving global leadership competencies.

Focus group interview analyses revealed that participants experienced realistic applicability through the program. In the web-based learning environment, realism is an important factor for enhancing learning effects [25]. As the program operated in real time, participants could listen to field stories told directly by field nurses and students, who were able to answer their questions about information previously obtained through lectures. Participants stated that the vivid field stories offered

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by students studying in US clinical and nursing education fields made their learning a valuable experience. International exchange programs included local visits to reinforce realism for nursing students [9,10,26]; therefore, it was meaningful to investigate whether there was a relationship between the effects of an online international program and realism. In particular, opportunities for students to listen to stories told directly by nurses or nurse specialists working at medical sites overseas about their work and roles can be considered as a means of increasing the sense of reality, which can otherwise be limited in web-based programs.

Participants expressed that their concerns and uncertainties about their future careers were addressed or clarified by listening to field stories about the clinical experiences of US nurses and nurse specialists and the practical experiences of students in the United States. It can be said that this program helped participants to refine the details and objectives of their career paths and specify active plans to achieve them. According to adaptive career decision-making theory, career decisions can be molded by personal experiences and stimuli from the outside world [27]. An international collaborative learning program such as that described in our study can assist fourth-year nursing college students in specifying their career paths by broadening their career horizons and providing specific information about how to realize their goals. Additionally, the program in the study included diverse topics: trends in US nursing education, comparison and analysis of nursing education systems in the United States and South Korea, role expectations in different medical settings based on stories from US nurses or nurse specialists, and comparison and analysis of clinical practice education through collaborative activities with local students. As shown in previous studies, participants experienced an increase in knowledge, thought, international perspective [10], and view of career paths and human relations [9]. The participants expressed that their international perspective was particularly broadened because the learning tasks undertaken prior to direct exchanges had provided a comparison and analysis of the South Korea and US systems. Findings support those of a previous study [28] that explored a prediction model of student achievement, which suggested that the assignment of learning tasks in web-based lectures can be an important factor affecting learning outcomes. The passive web-based learning process in this study was likely complemented by prior tasks and reinforced learners' self-directedness, further maximizing such expandability. The effects of self-confidence and expanded cognition [26] through international exchanges became possible via active question and answer periods and practical answers in the web-based environment.

Participants showed initiative in changing themselves and their environment through this program. After listening to field stories from the United States, they indicated that they recognized the need for comprehensive nursing care practices that respect patients' emotional and cultural needs. This result supports those from a previous study [29] in which nursing college students in clinical practices in US hospitals found, through web-based training, that patients in hospitals relied almost entirely on nurses who provided comprehensive nursing care. The participants additionally realized that perceived negative attitudes toward the nursing profession could be due to cultural differences rather than the nature of the profession; this realization led them to consider their profession more positively. Furthermore, their attitude toward nursing development became more positive as they perceived the image, status, and efforts of South Korean nurses more positively. This change in attitude is in line with results of a previous study [9] in which participants demonstrated greater pride in the nursing profession after participating in a short-term program abroad to increase their global health competencies. The participants in our study were able to accumulate more nursing knowledge as well as expand their psychodynamic perspective regarding its utilization in the field.

Students evaluated program quality highly overall, but the item on whether the program was intellectually challenging and stimulating had the lowest score. This could be improved by assessing the topics of interest of participating students before developing the program, including activities on identifying current relevant issues, and discussing them. As for the evaluation of the operation process, the strength of the program was that it was conducted online to allow students to participate during the semester without temporal and spatial constraints and burden of cost. Active interactions between learners and the outside world are important for higher learning effects [25]. When interactions are not active, there can be problems such as decreased immersion, lecture dissatisfaction, and an increase in dropout rates [30]; therefore, the program utilized a videoconferencing platform capable of interactive communication that encouraged students to participate in real-time collaborative activities actively, thereby enhancing the sense of immersion and quality of the program. The evaluation showed that discussing and preparing presentation materials in small groups allowed participants to improve their understanding of corresponding topics at each session and that there was a lack of time for 60-minute sessions with local nursing students. There was some confusion due to sessions progressing on different days of the week; therefore, we suggest that the next program should devote extended time to the program and utilize fixed days of the week for sessions. Evaluation of program content included requests for seminars with field nurses who had more diverse backgrounds or experiences (eg, work in different wards or attended graduate school), and for program levels subdivided by year in college (eg, freshman through senior).

This study has several strengths. The effectiveness of an online international collaborative learning program for nursing college students, developed within the restrictions imposed by the COVID-19 pandemic, was verified by combining quantitative data (surveys) with qualitative data (focus group interviews).

Limitations

Limitations exist because this was a single-group postdesign study, and there is no feasibility study for pre and postcomparison verification. It is necessary to conduct research to confirm the effectiveness of the program based on practical experiences and college grade levels of student participants. In addition, because most research on international exchange programs has focused on field trips, there were limited tools to

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verify the effectiveness of our web-based programs; therefore, it is necessary to develop a tool that reflects the characteristics of distance education to measure the effectiveness of the program.

Conclusions

Previous research on international exchange programs has focused on field trips, yet this study examined the program effectiveness of an online international collaborative learning program for nursing college students. We confirmed the effectiveness of the program in improving global leadership competencies during the COVID-19 pandemic, which had restricted the ability to operate traditional exchange programs between countries. We suggest conducting follow-up studies to verify the mid- to long-term intervention effects of continuous operation of the program, rather than one-off training, after planned incorporation into the nursing education global nursing course curriculum. We further suggest developing programs in connection with various organizations that utilize the advantages of web-based learning environments.

Authors' Contributions

DJ and JCDG conceived and designed the study. DJ was responsible for project administration and supervision. DJ, JCDG, EC, and KL collected and analyzed data. DJ, JCDG, EC, and KL wrote reviewed and edited the manuscript. All authors have read and approved the final manuscript.

Conflicts of Interest

None declared.

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Original Paper

Leveraging Machine Learning to Understand How Emotions Influence Equity Related Education: Quasi-Experimental Study

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Abstract

Background: Teaching and learning about topics such as bias are challenging due to the emotional nature of bias-related discourse. However, emotions can be challenging to study in health professions education for numerous reasons. With the emergence of machine learning and natural language processing, sentiment analysis (SA) has the potential to bridge the gap.

Objective: To improve our understanding of the role of emotions in bias-related discourse, we developed and conducted a SA of bias-related discourse among health professionals.

Methods: We conducted a 2-stage quasi-experimental study. First, we developed a SA (algorithm) within an existing archive of interviews with health professionals about bias. SA refers to a mechanism of analysis that evaluates the sentiment of textual data by assigning scores to textual components and calculating and assigning a sentiment value to the text. Next, we applied our SA algorithm to an archive of social media discourse on Twitter that contained equity-related hashtags to compare sentiment among health professionals and the general population.

Results: When tested on the initial archive, our SA algorithm was highly accurate compared to human scoring of sentiment. An analysis of bias-related social media discourse demonstrated that health professional tweets (n=555) were less neutral than the general population (n=6680) when discussing social issues on professionally associated accounts (χ^2 [2, n=555)]=35.455; *P*<.001), suggesting that health professionals attach more sentiment to their posts on Twitter than seen in the general population.

Conclusions: The finding that health professionals are more likely to show and convey emotions regarding equity-related issues on social media has implications for teaching and learning about sensitive topics related to health professions education. Such emotions must therefore be considered in the design, delivery, and evaluation of equity and bias-related education.

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KEYWORDS

bias; equity; sentiment analysis; medical education; emotion; education

Introduction

Research on addressing bias in health professionals found that feedback conversations about topics such as bias provoked defensive reactions [1,2]. However, these emotions did not hijack the learning process as learners still perceived their experience as positive while perceiving feedback about their biases as actionable [3]. This finding was unique in the feedback literature, which generally suggests that feedback should be targeted away from the self to avoid hijacking the feedback process [4]. This paradox suggests the need to further explore how emotions may mediate conversations about bias among health professionals.

Understanding the role of emotions when discussing topics related to bias or equity is essential to advance education in the field. We know that emotions play an important role in

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mediating the relationship between self-concept and learning. If confronted with their biases, learners may perceive a threat and therefore perceive the situation to have a negative attainment value leading to negative emotions. Negative emotions may then impede information recall and promote avoidance in processing its content [5]. Not all emotions have a negative influence on learning. For example, emotions are essential for transformative learning and similar methods that require dissonance, critical reflection, facilitated dialogue, action, and behavior change [6].

The importance of understanding emotions related to bias or equity education is especially salient when defensive or skeptical reactions are provoked. When challenging learners' perceptions regarding the erroneous beliefs that they are not biased, emotions can lead to the backfire effect, strengthening the belief in such erroneous information even after attempted refutation [7,8]. This could lead learners to expend considerable cognitive resources to counter refutation [9,10] and activate more evidence that supports their original erroneous beliefs.

In our previous work, we found that the idea of having bias and therefore being vulnerable to its effects was a threat to the strongly held belief among health professionals that they must operate without bias [11]. Research suggests that strongly held beliefs, such as the idea that health professionals cannot have bias, are integral to health professionals' sense of self [12,13]. Bias acceptance, therefore, may be perceived as identity threatening and trigger self-protective responses such as defensiveness and denial [14] to restore a sense of self-worth [15].

Research regarding emotions in health professions education can also be challenging for numerous reasons. For example, there are tensions in how emotions are conceptualized in health professions education. Some view emotions as a physiological response, others as skills or abilities, and others view emotions as a sociocultural mediator [16]. There are also ontological tensions and a lack of conceptual and methodological consistency [17]. Despite such challenges, a deeper understanding of how emotions influence learning is needed to enhance teaching and learning about emotionally challenging topics such as equity.

Advances in machine learning (ML) technology such as natural language processing (NLP) and sentiment analysis (SA) may provide a novel way of approaching such research [18]. ML techniques can automate information processing and have been applied towards applications such as competence assessments [19]. NLP is a form of ML that can structure and extract text-based information making it available for further analysis [20]. NLP and advanced text analytics are being used increasingly in a health care context [21,22]. SA is a mechanism of analysis that evaluates the sentiment of textual data by assigning scores to textual components and calculating and assigning a sentiment value to the text [23].

SA is most commonly discussed in business settings as it allows one to determine customers' overall sentiment about products and services through data scraping and analysis from social media [24]. In health care, SA has been used to analyze online comments regarding hospital services to explore patient experiences [25] and applied to electronic health records to analyze health professional behavior [26]. In another study, SA was applied to twitter health news to compare whether health news is delivered in a manner more consistent with facts or opinion [27]. In these examples, researchers acknowledged their lack of clinical experience and limitations in the execution of their analysis. For example, Gohil and colleagues acknowledge that their methods had not been tested for accuracy [26]. The potential for SA in health professions education research is therefore limited without further research and evaluation.

Our previous research on emotions and bias-related feedback may provide a window into the application of SA. More recently, a shift from in-class to online discussions on sensitive and emotionally charged topics may provide an opportunity for inquiry. A deeper analysis of the language used by health professionals on social media may therefore provide insight into the emotions associated with teaching and learning about equity and bias.

Overall, our aim for this study was to improve our understanding of the role of emotions in bias-related discourse. We, therefore, conducted an SA of bias-related dialogue among health professionals. First, we tested if our SA algorithm was accurate by testing the accuracy of our NLP library on an existing archive of bias-related discourse among health professionals. Second, we utilized our SA to compare if the sentiment toward equity-related online discourse differed between health professionals and the general population.

Methods

Sentiment Analysis

Sentiment is a thought, opinion, or idea based on the underlying feeling or emotion about a specific topic or item. SA is utilized to analyze text and assign the writer's attitude as positive, negative, or neutral given the presence of certain keywords. First, the text is split into four basic components: tokens, sentences, phrases, and entities. Next, an algorithm is applied using one of two systems. In a rule-based system, rules are manually crafted to analyze textual components. Specific words are scored as negative, neutral, or positive and associated with a score. These values are then tabulated to provide an estimate of the overall sentiment of the text. In an automatic system, machine learning technology is used to acquire knowledge from the data and allow for terms that are not currently within an existing set of rules. Both a rules-based and an automatic system can also be combined to utilize an initial database as a reference while also allowing for the inclusion of new terms and the alteration of sentiment values [28].

Step 1: Developing and Testing Our SA Algorithm

We developed a potential SA algorithm from an NLP library known as TextBlob. This library was built out of a toolkit using many different resources that are versatile and contain millions of training texts ranging from movie reviews to online conversations. TextBlob uses a naïve Bayes classifier which is a natural language toolkit (NLTK) that was trained from a movie review corpus. Millions of reviews were striped into tokens that

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were assigned positive or negative values to allow for the sentiment of the entire message to be interpreted.

Since naïve Bayes is a generative model while other approaches such as linear regression (LR) are discriminative, we felt that Naïve Bayes was a stronger model to use for a small data set which requires extending beyond the corpus that was originally used for training. This is only true if the assumption of independence holds, which is the case with our data. In addition, naïve Bayes performs well in the presence of categorical input variables, which is also the case in this study. Lastly, TextBlob is well documented and therefore is easy to integrate into our existing algorithm [29].

To determine the accuracy of our newly developed SA algorithm for our purposes, we utilized a pre-existing and de-identified data set of interviews with health professionals about their implicit biases. Ethics approval was not required for secondary analysis of de-identified data. We conducted SA on the transcribed interviews to score their underlying sentiment. We then compared the machine score with a manual human-scored sentiment categorization which had been completed prior to the algorithm execution. This comparison allowed us to determine the accuracy of the algorithm within the context of health professions' education and practice. We calculated the accuracy of our algorithm by calculating how many interviews were correctly computed in comparison to the manually scored value.

Step 2: Application of SA to Twitter Archive

We collected an archive of publicly available tweets, including metadata such as display name, username, and user biography through the Twitter Application Programming Interface (API). These "tweets" were stored if they included specific hashtags, which are commonly used to discuss bias-related topics. The hashtags included were "#AllLivesMatter/#ALM," "#BlackLivesMatter/#BLM," "#HeForShe," "#ImplicitBias," "#RepresentationMatters," and "#UnconsciousBias."

Our archive was then categorized into two databases, "health professionals" and "general population ."We distinguished between each group by searching for specific markers in the display name, username, or biography that were manually checked to ensure all individuals included in the data set would fit the classification of health professionals. The individuals whose "tweets" belonged to the general population had no additional criteria to be met other than using the hashtag.

The data collection process was initiated with the first official data pull on 12 January 2020 and collected for approximately three months, commencing on 29 March 2020, when the database was sufficient enough to analyze. The final archive contained 555 "tweets" from health professionals and 6680 tweets from the general population.

To compare sentiment scores between health professionals and the general population, the total sums in each of the three categories, "positive," "negative," and "neutral" were calculated for each of the two databases, "health professionals" and "general population." The purpose of the general population proportions was to serve as an expected value and to identify if health care professionals vary from this standard. This then allowed us to perform a chi-square goodness of fit test. We selected the chi-square goodness of fit test after methodological consultation with local experts in epidemiology and biostatistics. In general, a chi-square allows researchers to draw inferences and test for relationships between categorical variables. The goodness of fit test is useful to evaluate whether a full population is represented through the sample data. As our research sample sought to compare the sentiment between health professional discourse and the general population, we felt the goodness of fit test would be appropriate.

We noted that the volume of data being collected between the general population and health professionals was vastly different in quantity. We chose to use proportions as the quantity of data may have been misleading. As there were fewer health professional tweets included, we scaled down this group to have more tangible numbers for our statistical analysis. For example, on a given data pull, if there were 150/500 negative tweets from the general population versus 12/20 negative tweets from health professionals, the comparison of raw quantities would have skewed analysis and interpretation. Therefore, the observed values were comprised of the counts of each category in the health professional data set. The expected values were the proportion of each category in the general population data set scaled to the sum of the health professional data set. The standard significance value of .05 was maintained, and considering there were three categories, two degrees of freedom were present, and we concluded that an χ^2 value of 9.21 was required for the deviation from the general population to be deemed statistically significant.

Programming Specifications

Our SA algorithm was written in Python 3.0. This was an object-oriented program that used a class method to handle Twitter API credentials, authorize access to the database, and utilize the NLP as the "tweets" were retrieved. A class method refers to the structure of the algorithm, which means that the class, program code template, and method are bound to the class and not the object of the class. In programming, class refers to a descriptor of certain objects rather than the objects themselves. Our algorithm was developed into a Python script for each hashtag, and then a bash script file was written to allow ease of access to collect the data. A bash file refers to a text file that contains a series of commands. In this study, the bash file contained the commands to run the Python algorithms to collect data and populate the database. Overall, we used the same algorithm for both components of this study, accuracy testing and Twitter analysis. However, there were slight modifications, such as removing authentication from the local accuracy testing script as the data was retrieved locally.

Results

In order to test the accuracy of the NLP library for the interviews conducted, there were 53 health professionals, including registered nurses and medical doctors. When we tested the original algorithm, our tool was able to accurately identify more than the required number of underlying sentiments to be deemed valid.

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With 44 out of the 53 interviews (83%) being correctly assessed on sentiment with the utilization of the equation referenced, this returned an accuracy of 0.82, which was higher than the required threshold of 0.75. This concluded that using the TextBlob library was highly accurate but not subject to minor deviance. Nonetheless, it can still be utilized with high confidence when applied to a topic such as health care. Table 1 provides a breakdown of the scores.

When applying the algorithm to the tweets gathered, there was a noticeable difference in the sentiments between health care professionals and the general population. This discrepancy highlighted a smaller proportion of neutral tweets from health care professionals' professional accounts on social media. This difference was proven to be statistically significant.

When using the chi-square test equation for goodness of fit, a χ^2 value of 35.455 is achieved (χ^2 [2, n= 555]=35.455; P<.001). As this value is higher than the 9.21 required for significance to be achieved, the results can be deemed statistically significant. Thus, it can be stated that health care professionals attach more sentiment to their posts on Twitter than seen in the general population. Table 2 provides a more detailed breakdown of the scores and comparison. Table 3 and Table 4 provide an illustration of the sentiment scores. Table 3 shows that the sentiment of health care professionals was more positive, less neutral, and less negative than expected. Table 4 shows the variance in the sentiment between the tweets between health care professionals and the general population of tweets with the same specified hashtags. This figure suggests that tweets by health professionals were more positive, less negative, and approximately the same level of neutrality when compared to the general population of tweets. Table 5 provides a breakdown of sample tweets.

Table 1. The sentiment algorithm, TextBlob, on interviews of health care professionals regarding implicit bias in medicine

Group	Total interviews	Correctly scored	Accuracy
Pediatric physician	11	10	0.90
Pediatric nurse	10	8	0.80
Psychiatric nurse	11	10	0.90
Psychiatric resident	10	7	0.70
Psychiatric physician	11	9	0.82
Total	53	44	0.83

Table 2. The sentiment score of the tweets by health professionals and their associated chi-square values with intermediaries.

Sentiment Score	Observed	Expected	Difference	Difference Sq.	Difference Sq./Exp Fr.[a]
Positive	275.00	211.18	63.82	4073.3773	19.2889
Negative	42.00	70.70	–28.70	823.5057	11.6484
Neutral	238.00	273.13	–35.13	1233.8518	4.5175
Total					35.455[b]

[a]Expected Fraction.

[b]Chi-square statistic value which is used to determine statistical significance.

Table 3. The observed and expected values for sentiment score of the tweets by health professionals.

	Observed	Expected
Positive	275	211.18
Negative	42	70.7
Neutral	238	273.13

Table 4. The variance in sentiment between health care professionals and the general population with respect to the same hashtags.

	Health Professionals	General Population
Positive	45.66	38.22
Negative	5.2	12.74
Neutral	49.14	4904

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Table 5. Sample tweets from health care professionals and the general population with equity-related hashtags.

	Positive	Neutral	Negative
Health professionals	*It's #WomensHistoryMonth and #AMWA will be spotlighting incredible #womeninmedicine all month-long!*	*Please join us at the diversity in medicine conference #docswithdisabilities*	*Maybe if I work hard enough and almost die of COIVD my patients will start calling me "doctor" instead of "mademoiselle" #genderbias #womeninmedicine*
General population	*Moving from a safe place to a brave place to address issues of #implicitbias #CCM49 Great session thank you!*	*Check out this in-depth podcast…on educating scientific communities #implicitbias*	*Gender bias is not a good look #genderbias #checkyourgenderbias #unconsciousbias*

Discussion

Principal Findings

The finding that health professionals are more likely to show and convey emotions regarding equity-related issues on social media has implications for teaching and learning about sensitive topics related to equity and bias for health professionals. Such emotions are likely to influence learning processes and therefore must be considered in the design, delivery, and evaluation of equity and bias-related education.

Emotions and Identity in Health Professions Education

Our aims through this research were to gain further insight into how emotions influence equity and bias-related education through SA. By leveraging advances in ML technology, NLP, and SA, we developed, tested, and applied a novel SA algorithm to social media discourse. Our findings suggest that health professionals are more likely to convey emotions on social media about equity-related topics than the general public. Although previous research has found evidence that there are defensive reactions to discussions about bias among both health professionals and the general public [30-32], our SA findings suggest that health professionals may be uniquely susceptible to defensiveness and counter-react through positive emotion as a response.

This finding aligns with previous research on defense mechanisms to grapple with the reality of an individual's role in perpetuating prejudice or discrimination [33]. Our study suggests the evidence of reaction formation as a defense for learners. Reaction formation refers to when an individual forms an attitude that is the opposite of one's threatening or unacceptable actual thoughts [34]. By conveying a higher degree of positive sentiment, health professionals may be attempting to project that they are more neutral or objective when, in reality, they demonstrate the same degree of bias as the general population [35].

We also found that variance in sentiment between health professionals and the public suggests that not only do health professionals convey more emotion, but they also demonstrate greater sentiment variance related to positive emotion compared to the general public, who convey greater variance related to negative emotion. Greater positive sentiment among health professionals suggests that health professionals are utilizing Twitter differently than the general public. Therefore, our findings suggest caution for health professions educators who attempt to challenge normative thinking of health professionals as neutral or objective. Skilled facilitators may be necessary to mediate and regulate emotions among both teachers and learners when such challenges arise [36].

Emotions and Social Media

Social media discourse provides an opportunity to explore how individuals react to social issues and world events. Tweets provide a source of data that can be automatically classified according to sentiment to provide insights into the emotional nature of certain topics. Although SA has been previously used for digital marketing or opinion mining, its use in health professions education research has been to date quite limited.

Global events and social movements related to equity and bias, such as #BlackLivesMatter and #JusticeforGeorgeFloyd, underscore the importance of social media discourse as it relates to teaching and learning about bias. Such reactions among both health professionals and the general public during unexpected events can provide evidence for collective sense-making [37], social sharing of emotions [38], and individual strategies of approach/avoidance [39]. Emotions also mediate how contact between and among different social groups can effectively address prejudice [40]. As we set out to explore in our study, SA may be an effective tool to analyze such discourse.

Before it can be effectively applied, however, the limitations of SA require ensuring its accuracy and utility in a health professions education context. Our study provides an example of a SA algorithm that was tested for accuracy before being applied. This algorithm can be used in future research to analyze sentiment associated with social media discourse and may also have future applications to other types of archives such as electronic health records.

Sentiment Analysis in Health Professions Education

Advances in NLP applied to textual data for educational purposes are developing at a rapid pace. SA has demonstrated potential in evaluating instruction, designing policy, enhancing learning systems, and educational research [41]. For example, SA has been used to analyze students' feedback to improve teaching [42-44] and track students' emotions across longitudinal learning activities through learning diaries [44]. However, there is a paucity of research into how SA can be applied specifically in a health profession education context.

Our study provides an example and template for future researchers to develop and utilize SA for a variety of purposes. We also hope that our work can provide insights into the emotionally charged nature of teaching and learning about bias

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and inform future work to develop, implement, and evaluate antibias and antiracism curricula for health professions learners.

Key Implications and Future Directions

For health professions educators to effectively consider emotions in the design, delivery, and evaluation of equity or bias-related curricula, educators should anticipate defensive reactions when emotions are provoked and ensure skilled facilitation for sensitive or emotionally charged discussions. Our finding regarding the unique nature of social media discourse among health professionals and the public also suggests that health advocacy curricula must be augmented with information on digital aspects of advocacy. In addition, existing teaching and learning on digital professionalism may benefit from information regarding sentimentality and how digital aspects of communications differ from traditional media.

Limitations

A key limitation of a SA approach is that SA focuses on categorical aspects of sentiment value such as positive, negative, or neutral. This limits our ability to understand nuanced emotional states that reflect an individual's experience. Past research on how individuals cope with potentially threatening feedback related to their biases highlights that ambivalence may form an important component of how they can respond to identity threats and move forward towards change [45]. Additional research is therefore needed, particularly into how situations are perceived and the individual and social resources that individuals experience or have to cope with emotions that may interfere with learning.

Another important limitation of using NLP is that it requires the classification model to be trained. This requires intensive learning and manual categorization, and the most accurate models are still continuing to improve. However, the most efficient models have not been trained to categorize health care–specific data. While this research has proven a high accuracy rate (0.83), it must be recognized it is not all-encompassing and open to errors. Nonetheless, accuracy will only continue to improve, and in turn, these models will become more relevant. It will be important to ensure that health care data is used in these training processes.

Our study was conducted in 2019 when BERT (Bidirectional Encoder Representations from Transformers) models were less commonly used. Although such models allow for better sentence processing leveraging the architecture for the Corpus of Linguistic Acceptability, they require an extremely large corpus of testing data for models, which would not necessarily align with our criteria and potential limit accuracy.

Further, it is worth noting that an unavoidable bias exists within any NLP algorithm itself as a human-designed approach may be subject to the biases present in the training data set. This is an area of future work that should be considered as SA in health education evolves with larger data sets.

Lastly, we recognize that our SA was not developed using data from the general public; however, we believed that it would be reasonable to use on general public tweets due to previous research on defensive reactions to bias-related feedback in the general public that align with our previous studies, and other research.

Conclusions

To explore the role of emotions in teaching and learning about bias and equity for health professionals, we developed and tested a SA algorithm of bias-related discourse. We developed a highly accurate SA algorithm that demonstrated health professionals use a higher degree of emotion when communicating about bias on social media compared to the general population. Our findings support that emotions must be considered in the design, delivery, and evaluation of equity and bias-related education.

Acknowledgments

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Conflicts of Interest

None declared.

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Abbreviations

API: application programming interface
ML: machine learning
NPL: natural language processing
SA: sentiment analysis

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Original Paper

A Comprehensive COVID-19 Daily News and Medical Literature Briefing to Inform Health Care and Policy in New Mexico: Implementation Study

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Abstract

Background: On March 11, 2020, the New Mexico Governor declared a public health emergency in response to the COVID-19 pandemic. The New Mexico medical advisory team contacted University of New Mexico (UNM) faculty to form a team to consolidate growing information on severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and its disease to facilitate New Mexico's pandemic management. Thus, faculty, physicians, staff, graduate students, and medical students created the "UNM Global Health COVID-19 Intelligence Briefing."

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Objective: In this paper, we sought to (1) share how to create an informative briefing to guide public policy and medical practice and manage information overload with rapidly evolving scientific evidence; (2) determine the qualitative usefulness of the briefing to its readers; and (3) determine the qualitative effect this project has had on virtual medical education.

Methods: Microsoft Teams was used for manual and automated capture of COVID-19 articles and composition of briefings. Multilevel triaging saved impactful articles to be reviewed, and priority was placed on randomized controlled studies, meta-analyses, systematic reviews, practice guidelines, and information on health care and policy response to COVID-19. The finalized briefing was disseminated by email, a listserv, and posted on the UNM digital repository. A survey was sent to readers to determine briefing usefulness and whether it led to policy or medical practice changes. Medical students, unable to partake in direct patient care, proposed to the School of Medicine that involvement in the briefing should count as course credit, which was approved. The maintenance of medical student involvement in the briefings as well as this publication was led by medical students.

Results: An average of 456 articles were assessed daily. The briefings reached approximately 1000 people by email and listserv directly, with an unknown amount of forwarding. Digital repository tracking showed 5047 downloads across 116 countries as of July 5, 2020. The survey found 108 (95%) of 114 participants gained relevant knowledge, 90 (79%) believed it decreased misinformation, 27 (24%) used the briefing as their primary source of information, and 90 (79%) forwarded it to colleagues. Specific and impactful public policy decisions were informed based on the briefing. Medical students reported that the project allowed them to improve on their scientific literature assessment, stay current on the pandemic, and serve their community.

Conclusions: The COVID-19 briefings succeeded in informing and guiding New Mexico policy and clinical practice. The project received positive feedback from the community and was shown to decrease information burden and misinformation. The virtual platforms allowed for the continuation of medical education. Variability in subject matter expertise was addressed with training, standardized article selection criteria, and collaborative editing led by faculty.

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KEYWORDS

COVID-19; pandemic; daily report; policy; epidemics; global health; SARS-CoV-2; New Mexico; medical education

Introduction

On March 11, 2020, New Mexico Governor, Michelle Lujan Grisham, and the New Mexico Department of Health declared a public health emergency in response to the COVID-19 pandemic, after announcing 3 New Mexico residents tested presumptive positive for COVID-19 [1]. New Mexico Department of Health responded by creating the Medical Advisory Team, which brought together state officials, health care providers, and community members to compile and disseminate scientific findings, and create guidelines and recommendations to navigate the challenges of the pandemic. With the growing number of scientific publications and news reports and the potential for misinformation dissemination into the community, the Medical Advisory Team reached out to faculty at the University of New Mexico (UNM) to form a team to analyze and distribute reliable information to inform health care and public policy decisions for the state.

There was a high volume of both vital and inaccurate information available regarding COVID-19 [2,3]. To reduce information overload and misinformation, quality content had to be filtered and consolidated for state and health care leaders [4-6]. Researchers recommended the use of official public health organization websites as the most reliable source of information on COVID-19 preventative measures [7].

Prior to the COVID-19 pandemic, there was little guidance on methodology to generate comprehensive daily briefings. We aimed to provide guidance on how to create a daily briefing to address the high volume of information and misinformation. We surveyed the readers to determine if the briefing influenced their professional practice, if it was a main source of information, and if it helped combat misinformation. Readers also had the opportunity to share their thoughts on the briefings in free text.

During the first few months of the global pandemic, medical schools and various medical education governing bodies agreed that clinical medical education needed to be suspended due to high infectivity risk, limited COVID-19 testing supplies, and limited personal protective equipment (PPE). Studies have since assessed how psychologically and educationally detrimental it can be to study medicine in isolation. Participants in 1 study found an increase in depression, detachment from family and friends, and hopelessness, with a decrease in work performance and study time [8]. While virtual platforms are less ideal than in-person learning, learners found team-based projects to be more engaging [9,10]. Medical students were given the opportunity to take part in this project with the goal of increasing engagement during a difficult time of learning. We aimed to qualitatively determine if participation in the briefings showed net benefit to virtual medical education.

With a robust team of professionals, students, and volunteers, a comprehensive daily briefing was first disseminated on April 5, 2020, as the "UNM Global Health COVID-19 Intelligence Briefing." Here, we describe the process of creating such briefings, the usefulness of these briefings to the community and its leaders, as well as their benefit to virtual medical education.

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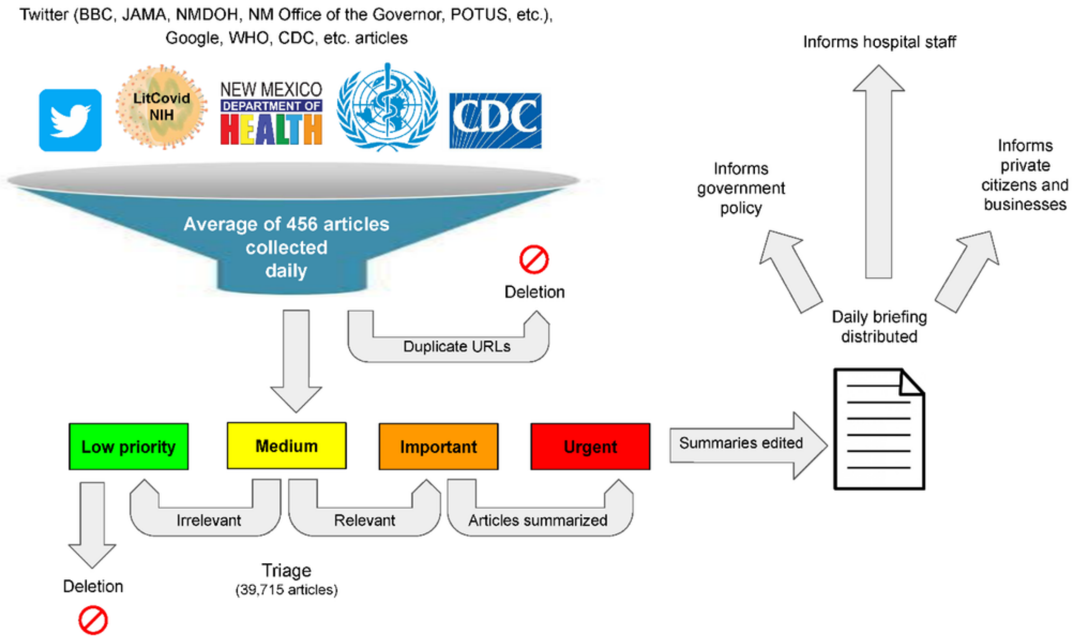
Methods

Briefing Process

A team of medical doctors, PhDs, journalists, graduate students, medical students, and researchers from both the United States and Kenya volunteered to participate in the composition of the daily briefings. Microsoft Teams served as the platform for automatic and manual article collection and triaging, composition of the briefing, as well as the administration of a qualitative survey. Microsoft Teams Flows were developed to automatically gather COVID-19–related papers and reports from various sources including Twitter (eg, BBC, JAMA, New Mexico Department of Health, New Mexico Office of the Governor, President of the United States), Google, LitCovid (National Institutes of Health), World Health Organization, and the Centers for Disease Control and Prevention while excluding duplicate URLs (Figure 1; Multimedia Appendix 1). Articles were categorized into "New Mexico Mainstream Media," "Manual Requests," "US Mainstream Media," "International Media," "Health Organization," "Science and Medicine," and "Literature" and were assigned a default "medium" priority tag through Microsoft Planner. Articles manually submitted by readers through a submission link from each briefing generated a Microsoft Teams Planner task and were reviewed and triaged accordingly. Triaging was completed by 3 administrators to ensure quality and consistency.

Figure 1. A conceptual overview of the methods used to generate the daily briefings. BBC: British Broadcasting Corporation; CDC: Centers for Disease Control and Prevention; JAMA: Journal of the American Medical Association; NMDOH: New Mexico Department of Health; POTUS: President of the United States; WHO: World Health Organization.



Articles were manually triaged by administrators into "urgent," "important," or "low" priority groups. Scientific reports were triaged based on the veracity and potential impact on COVID-19–related health care or public policy response. Information on epidemiology, testing, public guidelines, medical practice guidelines, new therapies, vaccines, and pathogenesis were of primary focus. Evidentiary priority was given to systematic reviews of randomized controlled trials with meta-analyses and individual randomized controlled trials, followed by quasiexperimental, case control, or cohort studies. These were often labeled "urgent." Studies with small sample sizes or problematic study designs were included or excluded at the triaging administrator's judgment. Opinions pieces were largely excluded. News articles covering New Mexico, United States, and international pandemic responses and impacts were included based on relevance and content validity.

Articles labeled "important" were analyzed and summarized by a team member to include the type of study, pertinent results, other relevant information, the Digital Object Identifier, or hyperlink, and marked as "complete." Headlines were carefully constructed to be as informative as possible rather than as "teasers." Completed articles were autopopulated first into a Microsoft Excel spreadsheet, then relocated to a Microsoft Word document. Items typically triaged as "low" priority were commentaries, editorials, political messages, and non–evidence-based studies, and excluded from the briefing. The briefing was divided into the following sections: "Executive Summary;" "New Mexico Highlights;" "US Highlights;" "Economics, Workforce, Supply Chain, PPE Highlights;" "Epidemiology Highlights;" "Healthcare Policy Recommendations;" "Practice Guidelines;" "Testing;" "Drugs, Vaccines, Therapeutics, Clinical Trials;" and "Other Science." Volunteers collaboratively edited the document with videoconference coordination each evening to ensure quality, clarity, accuracy, grammar, and proper citation. Reports with insufficient sample size, unclear conclusions, or poorly executed study designs were excluded. The final document included an "Executive Summary" with the general content, a disclaimer noting the inclusion of non–peer-reviewed content, and a list of all the participants of the day. The finalized briefing was emailed to the New Mexico Medical Advisory Team, sent to a listserv of subscribers, and posted on the publicly accessible

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UNM digital repository [11]. The UNM Department of Internal Medicine also incorporated the briefing into its daily department email. Listserv subscribers consisted of health care providers, researchers, and government employees, as well as UNM faculty, students, and readers not involved in health care or state policy. The UNM Digital Repository runs on BePress, which tracks global downloads of the briefings. The briefings have also been indexed by Google Scholar. There was no monetary gain associated with the creation of these briefings, with full access provided free of charge.

COVID-19 Global Health Briefing Survey

To assess the usefulness of the briefings to New Mexico policy makers, researchers, educators, physicians, and other health care professionals, an 18-question survey was created through Microsoft Forms, approved by the Institutional Review Board (20-263), and distributed to all briefing recipients. Survey participant demographics included academic degree(s) and place of occupation. We determined if participants provided direct clinical care to COVID-19–positive patients, if the briefing was their primary source of information regarding the pandemic, and how likely they were to share the briefing with colleagues.

To determine the briefing's usefulness to the respondent, we assessed the following on a scale from strongly disagree to strongly agree:

1. The daily briefing has informed or changed my response to the COVID-19 crisis.
2. I have gained relevant knowledge I wouldn't have otherwise because of this briefing.
3. This briefing has enabled me to combat misinformation.
4. This briefing has enabled me to clarify information I have seen elsewhere.

Lastly, the respondent could respond in free text how information from the briefing was applied professionally or personally and if they had comments or suggestions to improve the briefings.

Medical Education

Medical student education in the hospital setting was suspended, and students were not involved in direct patient care during the initial surge of COVID-19 around the globe. The UNM School of Medicine created a virtual COVID-19 course to allow for virtual didactics as well as asynchronous, self-directed learning. This course allowed students to be involved in various projects and, with curriculum committee approval, receive a 4th year elective credit for those efforts. A few students who were involved in the briefing proposed to the UNM School of Medicine curriculum committee that contribution to the briefings should count as course credit. The UNM School of Medicine approved the proposal.

Medical students were involved in manual submission of information, summarizing articles, editing the briefings every evening, and recruiting other students to join the project. The students also assisted in the assembly of the COVID-19 global health briefing survey. Lastly, the compilation and analysis of the data in this publication was entirely led by medical students who took part in various stages of the COVID-19 briefing development and dissemination.

Results

Briefing Process

Microsoft Teams Flows gathered an average of 456 articles daily, and 560 articles were manually submitted. A total of 39,715 articles were gathered throughout this project. Between April 5, 2020, to June 30, 2020, 58 UNM Global Health COVID-19 intelligence briefings were generated and published through the efforts of 68 individuals, including 19 faculty members, 31 medical students, 3 graduate students, 1 postdoctoral fellow, 3 staff members, and 11 contributors from outside of the UNM.

Each briefing was directly emailed to 176 members of the New Mexico Medical Advisory Team before the availability of the listserv on April 27, 2020. By June 30, 2020, the listserv had 400 subscribers. The UNM Department of Internal Medicine included the briefing in its daily newsletter sent to 525 members. By June 30, 2020, the briefing was sent to 1080 unique email addresses—693 within the UNM Health and Sciences Center and 387 outside of it.

Beginning April 24, 2020, all briefings were uploaded to the UNM Digital Repository for public access. The number of briefing downloads is plotted both daily and cumulatively in Figure 2. Between April 24, 2020, and July 5, 2020, there were 5047 downloads, with an average of 74 downloads per day. The highest number of downloads for an individual briefing was 260 (April 27, 2020). The average number of downloads was 85, the median 72, the maximum 260, and the minimum 4.

Throughout its entire duration, the briefings were downloaded in 116 countries (Figure 3). The 5 countries with the most downloads were the United States with 2164, Brazil with 235, India with 233, Canada with 224, and Germany with 224.

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Figure 2. Bar graph showing downloads per day and total downloads over time.

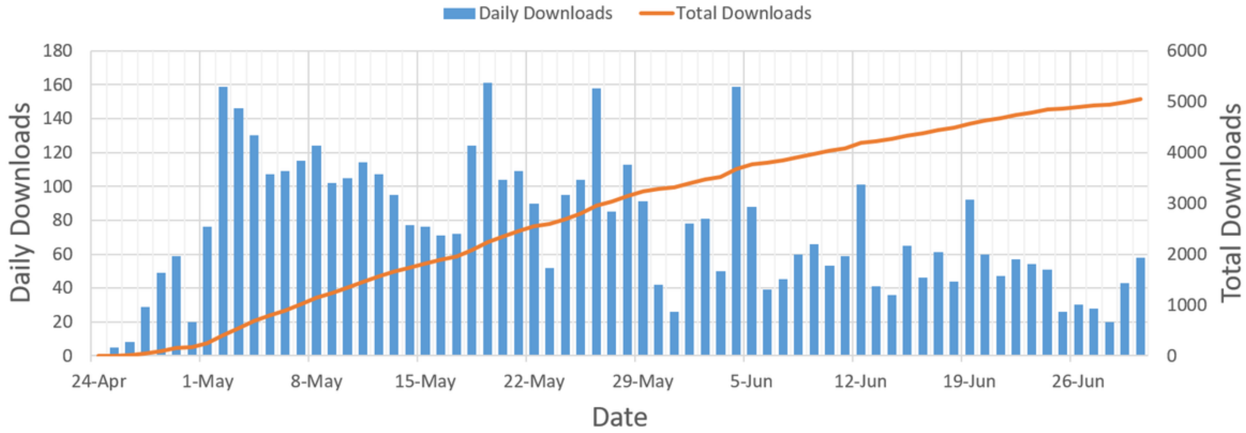

Figure 3. The number of downloads of University of New Mexico daily briefings per country from April 24, 2020, to July 5, 2020.

COVID-19 Global Health Briefing Survey

To evaluate the usefulness of the briefings, we sent an electronic survey to approximately 994 readers. A total of 111 individuals (approximately 11%) responded between May 8 and May 19, 2020. Among the 111 responders, 41 (37%) were physicians, 41 (37%) nonclinical academic faculty, 9 (8%) administrators, 8 (7%) academic staff, 5 (5%) government employees, 4 (4%) students, and 3 (3%) nurses. Of the 111 respondents, 30 (27%) were involved in providing direct clinical care to COVID-19 patients, 47 (42%) had MD or DO degrees, 34 (31%) had PhDs, and 9 (8%) had MPH degrees. The health care providers who responded (n=30) had an average of 19 years of clinical practice (95% CI 15-23).

A majority of respondents (105/111, 95%) agreed or strongly agreed that the briefing helped them gain relevant knowledge, 71% (79/111) changed their response to the pandemic, 79% (88/111) reported the briefings helped them combat public misinformation, and 89% (99/111) said it helped to clarify the information from other data sources (Figure 4). Moreover, 24% (27/111) of respondents cited the briefing as their primary source of information on the pandemic, and 73% (81/111) reported having shared the briefing with their colleagues. On a scale of 0 (“would never share”) to 10 (“will definitely share”), the respondents reported being very likely to continue to share the briefing with colleagues (mean score 8.8, 95% CI 8.5-9.1).

The briefings influenced New Mexico state government response to the pandemic. David Scrase, the New Mexico Cabinet Secretary for Health and Human Services, informed our team that the daily briefing influenced dozens of policy decisions including the following: (1) mandating universal mask use in New Mexico early in the pandemic; (2) expansion of remdesivir treatment; (3) caution about hydroxychloroquine treatment; (4)

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selecting R_effective as a key gating criterion for the state (COVID spread rate); (5) guiding the adequacy of the PPE supply chain (particularly overseas); and (6) recommending against the use of antibody testing as an adjunct to clinical (or patient) decision making (David R Scrase email communication, June 16, 2020).

The briefings also received positive feedback from other health and policy officials around the state, including the UNM associate dean of Continuous Professional Learning, the Presbyterian chief medical and transformation officer, the vice chair of veterans' affairs, the vice chancellor for clinical affairs, lead of New Mexico Medical Advisory Team, and the president and chief executive officer of Christus St. Vincent Regional Medical Center (Table 1).

Figure 4. Survey responses from "strongly disagree" to "strongly agree".

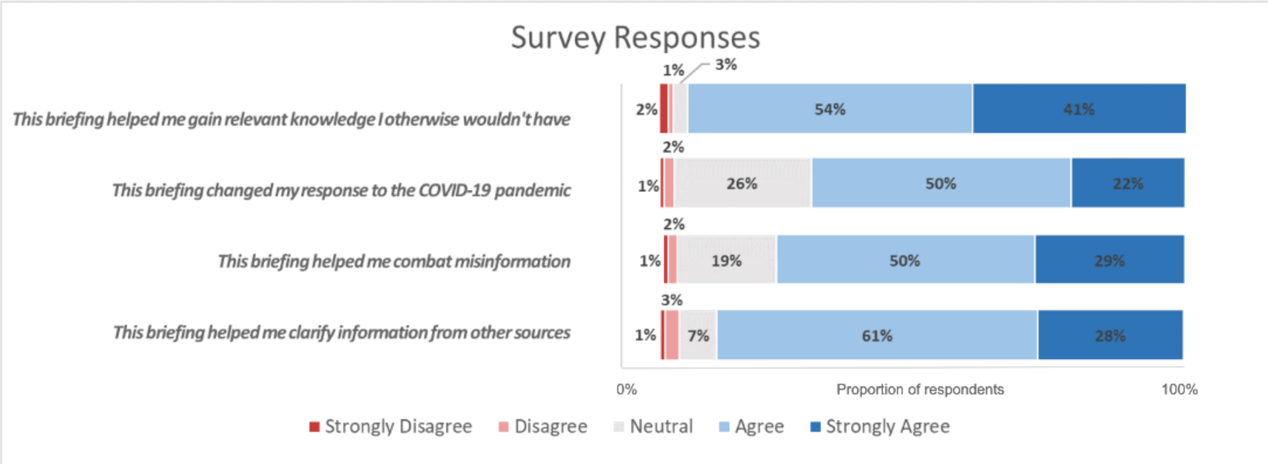

Table 1. Direct quotes from health care and policy officials across New Mexico regarding the impact of the University of New Mexico briefings.

Author	Statement
Associate dean of Continuous Professional Learning at UNM[a]	• "I recently became aware of the great work that you and colleagues are doing to cull through the infodemic to provide useful updates. I'd be grateful if you could add me to the distribution for the DAILY UNM GLOBAL HEALTH COVID-19 BRIEFING"
Presbyterian chief medical and transformation officer	• "These are amazing! Can you help me get on the distribution list?"
Vice chair veteran's affairs	• "This compendium is excellent!"
Vice chancellor for clinical affairs, lead of New Mexico MAT[b]	• "I wanted to let you know that you and the team know that your briefing is being sent to the PHS[c] leadership team. It is getting rave reviews."
Executive vice president and chancellor for HSC[d]; dean of School of Medicine	• "You're doing a great job." • "Thank you and your team again...for this very comprehensive review of information. It is very useful."
President and chief executive officer of Christus St. Vincent Regional Medical Center	• "These are excellent briefs. Thank you for sharing."
New Mexico cabinet secretary for Health and Human Services Department	• "This is just so incredibly helpful… I really appreciate you taking the initiative to do this. Will provide daily highlights to gov and staff."

[a]UNM: University of New Mexico.
[b]MAT: medical advisory team.
[c]PHS: public health service.
[d]HSC: Health and Sciences Center.

Medical Education

The UNM Global Health COVID-19 Intelligence Report project enhanced medical student education. A total of 31 medical students contributed to the creation of the daily briefings. Participation in the project was approved for course credit by the UNM School of Medicine curriculum committee. The students were able to practice the analysis and quality assessment of scientific data, and they found participation in the briefings to be informative and rewarding (Textbox 1).

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Textbox 1. Direct quotes from medical students regarding the impact of the briefings on medical education.

Medical students' statements

- "[The briefing] provided a meaningful purpose as we were able to contribute directly to our community's wellness …. I appreciated participating, seeing daily updates, and knowing hospital teams were making real time policy changes with the help of the information provided in the reports."
- "Once the COVID-19 block started it was refreshing to use my skills to analyze articles because I was already doing so on my own… It was great to be able to create deliverables as part of the project and feel like I was making an impact to the state of New Mexico, which eased my anxiety significantly."
- "This style of project is immensely helpful for students who want to be more involved with research and have a limited history of working in research. I hope that every project I work on subsequently will be so well organized."
- "Participating in the daily briefing helped me stay connected to the ever-changing world of COVID research. In a world of information overload, helping with this project grounded me to the primary information coming out of the scientific world. I felt confident giving friends and family advice and educating them on this pandemic because of the briefing."
- "Being involved in this project has helped me learn more about this novel virus and feel more confident about the information I can disseminate to my friends and family. It also taught me about how difficult it can be to find trustworthy news, and how much of a problem can misinformation be. Even my parents (who are college educated with scientific degrees) presented wrong information to me many times. This reminded me of the importance of reliable news sources these days, and how we struggle to find them."

Discussion

Strengths and Principal Findings

The development of the briefing succeeded in informing the practice of physicians and other health care personnel, facilitating COVID-19 research efforts by faculty and staff in academia, influencing policy making by the government of New Mexico, and alerting the public about the most relevant developments as is evident in our survey results. Additionally, the briefings were accessed by approximately 3 times the number of people compared with those who were directly emailed and catered to an audience beyond the scientific and medical community as the categorization of articles with headers and summaries reported in everyday language.

This project also succeeded in allowing for the continuation of medical education during the initial surge of COVID-19 when medical students and research students were prohibited from their normal duties. The learners improved on their ability to analyze a scientific paper and helped them empathize with the public regarding misinformation. The students reported being part of a community project to be meaningful and that influencing the health of New Mexico reduced student anxiety of being away from direct patient care.

The utilization of a listserv and online archive helped expand the audience beyond medical advisory team and the state of New Mexico to the briefing's eventual global reach. Organizing interest through a listserv would help disseminate the material quicker and broader should another similar endeavor be attempted.

Due to both limited funding and volunteers, the effort was brought to a close as the final briefing was published on June 30, 2020. We were unable to continue the production of thorough, high-quality publications free of charge due to the inevitable loss of many of our volunteers. We were unable to replace team administrators and leadership to triage daily and ensure quality control. Medical students returned to clinical duties, and faculty were unable to simultaneously sustain this unfunded effort along with their teaching, research, and administrative responsibilities. Between April 9, 2020, to July 2, 2021, a similar COVID-19 briefing effort was created ("COVID-19 Literature Surveillance Team") of medical students and faculty, who were able to continue their reports by changing their daily briefing to weekly [12]; however, this team ultimately discontinued publication [13]. Our COVID-19 briefing efforts were closed with a presentation that expressed gratitude to all who participated [14].

Limitations

Contributors and authors of the briefings had variable expertise in assessing scientific literature. Initially, all participants were allowed to triage content. Due to quality concerns, triaging was reduced to 3 administrators. It was not obvious how to standardize the judgment process that went into rapid decision-making regarding article inclusion. Those triaging needed to be aware of the prior body of work addressed, be able to analyze an article quickly, and be well versed in various research methodologies and their assessment. Standardized training for editors and authors was implemented to improve the consistency and quality of article summaries.

Initial article selection was less stringent and included more speculative reports. More selective criteria were implemented over time. The inclusion of articles of varying evidence, such as preprints, received criticism. Recent studies have shown that the standard in preprints for the life sciences is similar to that of peer-reviewed articles; therefore, they can be considered valid scientific contributions [15]. As a clarification, our later briefings included the source and type of study (preprint, meta-analysis, Reuters, etc) before each summary.

A major concern was the disagreement between global governing entities on treatment and the quickly evolving understanding of the virus. For example, the US Food and Drug Administration granted emergency use authorization for both chloroquine and hydroxychloroquine for certain hospitalized COVID-19 patients on March 28, 2020, whereas the European Union did not allow for its use. The emergency use authorization was revoked on June 15, 2020, due to side effects of the medications.

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While our survey was disseminated to all subscribers of the briefing, persons who may have derived less value from the briefings or had more substantial criticism of the publication were not well represented among the respondents. While favorable impact ratings were provided by survey respondents, our free-text section (on how the respondent-applied information from the briefing influenced their active response to the pandemic) could have benefitted from more specific wording to solicit specific uses. The most substantive feedback came from a nonsurvey source, namely Secretary Scrase via email.

Comparison to Prior Work and Future Directions

Other programs have released daily briefings [16,17,18,19,20] in similar efforts to combat information overload and implement quality control during the COVID-19 pandemic. At the time of this publication, there has been no research that has compared briefing dissemination to other forms of information dissemination during a rapidly changing health crisis. The pandemic has shifted the scientific community toward a more robust and rapid data-sharing culture [21]. Future work could compare the efficacy of briefings compared to other measures to alter and improve policy and information dissemination.

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Authors' Contributions

LJ: administrative support (student lead for the COVID-19 curriculum; organizing, recruiting, and training students), briefing content, briefing editing, briefing triage, survey development, drafting substantial portions of the manuscript, and critical revisions to the manuscript. JS: briefing content, briefing editing, and manuscript draft and revision. RDK: administrative (student leader for COVID-19 block 1), founding member, briefing content, briefing editing, briefing triage, and manuscript revisions. EM: student coordinator for continuing education, founding member, student leader, briefing content, briefing editing, briefing triage, and manuscript revisions. HG: training material development, briefing triage, briefing content, briefing editing, and manuscript revisions. RO: briefing content, briefing editing, survey development, data analysis, drafting substantial portions of the manuscript, and critical revisions to the manuscript. MC: briefing content, briefing editing, survey development, data analysis, drafting substantial portions of the manuscript, and revisions to the manuscript. AR: briefing content, briefing editing, and manuscript drafting. AM: briefing content, briefing editing, and manuscript draft and revision. JT: briefing content, briefing editing, and manuscript draft and revision. RFK: briefing content, briefing editing, briefing triage, and manuscript drafting and revisions. SP: briefing content, briefing triage, and manuscript drafting. AP: briefing content, briefing triage, and briefing editing. AH: administrative, briefing content, and manuscript drafting. AY: briefing content, briefing editing, and briefing triage. TC: briefing content, briefing editing, and survey development. LTE: briefing content, briefing editing, and manuscript revisions. FN: briefing content, briefing editing, and manuscript revision. EW: briefing content and briefing editing. ME: briefing content, briefing editing, and manuscript revision. JL: briefing content and briefing editing. DR: briefing content, briefing triage, and manuscript revisions. JL: organization and obtaining institutional approval for a medical student COVID-19 elective workforce; contribution to the conceptual design of the manuscript; briefing editing; and manuscript editing. LS: administrative support, briefing content, briefing editing, briefing triage, dissemination activities, survey development, data analysis, and substantial manuscript draft and revision. IH: briefing content from medRxiv, bioRxiv, PsyArXiv, and arXiv. COO: briefing content. PKO: briefing content. SBA: briefing triage, briefing editing, manuscript revisions, and administrative tasks (Kenyan group). EOM: briefing content. PK: software infrastructure and maintenance, technical maintenance, briefing triage, briefing content, and briefing editing. NL: software infrastructure and maintenance, technical maintenance, briefing triage, briefing content, and briefing editing. SS: administrative tasks and briefing editing. AN: briefing triage, content, editing, and manuscript editing. CGB: briefing content, briefing editing, briefing triage, dissemination activities, survey development, and critical revisions to the manuscript. TIO: briefing editing, briefing content, dissemination activities, and manuscript editing. KT: briefing content, briefing editing, and manuscript editing. OM: briefing content and briefing editing. DJP: briefing content and briefing editing. CGL: project and editorial leadership, software infrastructure and maintenance, briefing content, briefing editing, briefing triage, technical maintenance, dissemination activities, survey development, and critical revisions to the manuscript.

Conflicts of Interest

None declared.

Multimedia Appendix 1
Data accumulation.
[DOCX File , 20 KB - mededu_v8i1e23845_app1.docx]

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Abbreviations

PPE: personal protective equipment
UNM: University of New Mexico

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Original Paper

Real-life Evaluation of an Interactive Versus Noninteractive e-Learning Module on Chronic Obstructive Pulmonary Disease for Medical Licentiate Students in Zambia: Web-Based, Mixed Methods Randomized Controlled Trial

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Abstract

Background: e-Learning for health professionals in many low- and middle-income countries (LMICs) is still in its infancy, but with the advent of COVID-19, a significant expansion of digital learning has occurred. Asynchronous e-learning can be grouped into interactive (user-influenceable content) and noninteractive (static material) e-learning. Studies conducted in high-income countries suggest that interactive e-learning is more effective than noninteractive e-learning in increasing learner satisfaction and knowledge; however, there is a gap in our understanding of whether this also holds true in LMICs.

Objective: This study aims to validate the hypothesis above in a resource-constrained and real-life setting to understand e-learning quality and delivery by comparing interactive and noninteractive e-learning user satisfaction, usability, and knowledge gain in a new medical university in Zambia.

Methods: We conducted a web-based, mixed methods randomized controlled trial at the Levy Mwanawasa Medical University (LMMU) in Lusaka, Zambia, between April and July 2021. We recruited medical licentiate students (second, third, and fourth study years) via email. Participants were randomized to undergo asynchronous e-learning with an interactive or noninteractive module for chronic obstructive pulmonary disease and informally blinded to their group allocation. The interactive module included interactive interfaces, quizzes, and a virtual patient, whereas the noninteractive module consisted of PowerPoint slides. Both modules covered the same content scope. The primary outcome was learner satisfaction. The secondary outcomes were usability, short- and long-term knowledge gain, and barriers to e-learning. The mixed methods study followed an explanatory sequential design in which rating conferences delivered further insights into quantitative findings, which were evaluated through web-based questionnaires.

Results: Initially, 94 participants were enrolled in the study, of whom 41 (44%; 18 intervention participants and 23 control participants) remained in the study and were analyzed. There were no significant differences in satisfaction (intervention: median 33.5, first quartile 31.3, second quartile 35; control: median 33, first quartile 30, second quartile 37.5; *P*=.66), usability, or knowledge gain between the intervention and control groups. Challenges in accessing both e-learning modules led to many dropouts. Qualitative data suggested that the content of the interactive module was more challenging to access because of technical difficulties and individual factors (eg, limited experience with interactive e-learning).

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Conclusions: We did not observe an increase in user satisfaction with interactive e-learning. However, this finding may not be generalizable to other low-resource settings because the post hoc power was low, and the e-learning system at LMMU has not yet reached its full potential. Consequently, technical and individual barriers to accessing e-learning may have affected the results, mainly because the interactive module was considered more difficult to access and use. Nevertheless, qualitative data showed high motivation and interest in e-learning. Future studies should minimize technical barriers to e-learning to further evaluate interactive e-learning in LMICs.

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KEYWORDS

distance education; randomized controlled trial; personal satisfaction; knowledge; user-centered design; chronic obstructive pulmonary disease; interactive; noninteractive; low- and middle-income country; LMIC; mobile phone

Introduction

Background

Medical education in sub-Saharan Africa (SSA) has expanded significantly in the last 3 decades as countries in the region have tried to address the critical shortfall of key health workers [1]. However, several factors threaten to impede developments on this front. These include a lack of teaching infrastructure and adequately trained medical teaching staff and the challenges many health professionals face as they attempt to manage heavy teaching workloads alongside priorities in clinical practice [1]. Another factor that affects advances in training clinicians is *brain-drain*—health professionals with critical teaching skills and experience relocate to high-income countries (HICs) in pursuit of better remuneration and employment conditions [2]. Although these systemic challenges threaten to impede medical education, there is a critical need to find ways to improve the educational and teaching experiences of students and lecturers in low-income settings, in which e-learning has been explored as a catalyst [3].

e-Learning is considered as potent as traditional classroom learning alone in a low-resource context [4], with several benefits. For instance, materials can be accessed at any time and in any geographic location using an internet connection, content may be available for offline access after download, and materials can be studied at the student's own pace [5,6]. Furthermore, e-learning access is scalable, thus facilitating teaching large numbers of students, and updating the content is also more efficient [6]. e-Learning is considered potentially cost-effective owing to reduced costs of instruction, travel, and classroom infrastructure [5-7]. However, the initial implementation of e-learning and its running costs are expensive, which can be a challenge, especially in low- and middle-income countries (LMICs) [4,5,8]. Often, e-learning in LMICs does not progress past the pilot stage because the e-learning approach is not adapted to the individual needs of the institution and is frequently not implemented sustainably—a phenomenon coined *pilot-itis* [8].

As with traditional classroom learning, e-learning is a heterogeneous learning method, which means there are different ways of learning on the web. An aspect is the difference between interactive and noninteractive e-learning. Interactive e-learning is defined as content that reacts to a learner's actions [9]. Examples of interactive e-learning include quizzes, interactive interfaces, virtual patients, and serious games. Virtual patients often involve learners in interactive clinical scenarios with a virtual person to teach clinical reasoning skills [10]. Serious games are technology-based games to teach a certain skill, mindset, or provide information [11]. Noninteractive e-learning, on the other hand, is defined as learning through static, nonresponsive web-based resources, such as PowerPoint slides without interactive elements, PDF scripts, or videos [3,12].

In health education research, interactive e-learning is often deemed more effective than noninteractive e-learning. Several studies in HICs have shown a positive effect of interactive e-learning on user satisfaction or knowledge compared with noninteractive e-learning [13-19]. In addition, knowledge frequently increases when user satisfaction is high [13,14,18]. However, studies comparing an interactive e-learning method with a noninteractive e-learning method for health care personnel in LMICs are rare, which potentially makes assumptions about the effectiveness of interactive e-learning in LMICs difficult for lecturers and other stakeholders. A study conducted in Colombia, an upper-middle–income country, compared learning on the commonly used e-learning platform Moodle with learning using an interactive intelligent tutor system. The latter fared better in their evaluation of medical students' knowledge, learning efficiency, and usability [20].

An e-learning system for medical licentiate (ML) students was set up in 2016 at the Chainama College of Health Sciences in Lusaka, Zambia, which is now part of the Levy Mwanawasa Medical University (LMMU). In addition, third- and fourth-year students received tablets to facilitate e-learning access [21,22]. The e-learning system was then assessed using a mixed methods format and considered functional in these settings. However, the program faced some challenges, as students' and lecturers' use of the e-learning platform was low. Possible explanations were the low quality of the tablets used and insufficient training with the technology. Another shortcoming was the low availability of diverse and multimedia e-learning content, as mainly noninteractive materials were available [21-23].

This study aims to contribute to the multimedia e-learning content at the LMMU by providing targeted e-learning materials on chronic obstructive pulmonary disease (COPD). COPD is a noncommunicable, chronic but preventable disease that occupies the seventh place in the worldwide list of years of life lost [24,25]. Of 196 million people >40 years in SSA, approximately 26 million were estimated to have COPD in 2010, and the literature suggests that >80% of COPD deaths occur in LMICs worldwide [26,27]. To treat COPD, health care workers need

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to be aware of the disease, its diagnosis and management, and adequate guidelines, such as the international guidelines of the Global Initiative for Chronic Obstructive Lung Disease (GOLD) [25]. However, this is not sufficient, as COPD is mostly underrepresented in medical education in SSA, leading to COPD underdiagnosis [28-32]. Improved COPD education for health care workers in low-resource settings is essential, as smoking and old age—the disease's key cause and risk factor, respectively—have been increasing in LMICs, predicting growth in COPD cases [25].

Study Objectives

The overarching objective of this web-based study is to compare learning outcomes from an interactive and noninteractive e-learning module on the topic of COPD for ML students following a mixed methods randomized controlled trial (RCT). The aim was to improve the understanding of real-life e-learning quality and delivery at the LMMU. Subsequently, the primary outcome for this study was user satisfaction, and the secondary outcomes were usability, short- and long-term knowledge gain, and barriers to e-learning access for ML students. These outcomes were determined quantitatively by web-based questionnaires and qualitatively by web-based rating conferences that explored how students experienced e-learning. On the basis of findings from previous studies, we hypothesized that an interactive e-learning module would be more effective in increasing learners' satisfaction and knowledge gain than a noninteractive module. It should be noted that most previous studies were conducted in HICs and not in a low-income setting.

Methods

Overview

This study adheres to the CHERRIES (Checklist for Reporting Results of Internet E-Surveys) checklist and the CONSORT-EHEALTH (Consolidated Standards of Reporting Trials of Electronic and Mobile Health Applications and Online Telehealth) guidelines for reporting eHealth and mobile health RCTs (Multimedia Appendix 1) [33,34]. Qualitative data results are presented according to the COREQ (Consolidated Criteria for Reporting Qualitative Research) checklist [35]. This mixed methods study used an explanatory sequential design in which qualitative findings were used to clarify quantitative results.

Study Setting and Design

The RCT with an allocation ratio of 1:1 took place in Zambia, a lower-middle–income country. The trial was conducted on the web at the LMMU in Lusaka, Zambia, for 11 weeks between April and July 2021. The LMMU was established in 2018 and has become the largest health training institution in the country and the fourth public university [36]. e-Learning at the Chainama College of Health Sciences, now part of the LMMU, was successfully implemented in 2016/2017. The study design aimed to evaluate interactive and noninteractive e-learning in a real-life setting, meaning no study-related and specific e-learning training was provided [21-23].

Ethics

The study protocol was approved by the ethics committee of the Heidelberg University and the local ethics committee of the LMMU (Heidelberg S-691/2020; LMMU 00007/20). The trial was not registered in accordance with the International Committee of Medical Journal Editors [37].

Study Sample

ML students in their second, third, and fourth year of the Bachelor of Clinical Sciences program at the LMMU were invited to participate. It was assumed that existing knowledge on COPD was low and that all students had computer literacy, as the technology experience of ML students was assessed to be moderate in 2017 [23]. As there were only approximately 200 ML students in the second, third, and fourth year in the Bachelor of Clinical Sciences program at the LMMU, instead of a sample size calculation, a convenience sample of all eligible students was chosen. A sample size of approximately 50 participants was deemed feasible, considering consent and attrition rates.

Study Materials

Development and Testing

With the aid of FN, who received training at the center for key competencies in didactics at the Heidelberg University, ES developed both e-learning modules. The modules were then uploaded for asynchronous use on the e-learning platform Moodle. Given the e-learning implementation in 2016/2017, it was assumed that all students had access to the e-learning platform and electronic devices [21-23]. Three study team members (FN, PA, and ES) tested the web-based e-learning material before the trial on different digital devices, such as desktop computers and smartphones. Changes were incorporated before the start of the study, and no further changes were made.

Content

Both modules contained key information from the GOLD report 2021, specialist literature, and pulmonological experts [25,38, 39]. The GOLD report is a document published annually that summarizes global information on COPD through the latest scientific literature. Essential knowledge on COPD definition, epidemiology, etiology, symptoms, diagnosis, severity assessment, differential diagnosis, therapy, and prognosis was included in the e-learning modules at the appropriate level according to the curriculum of the ML program. By continuously comparing slides on subtopics and copying and pasting information from one module to the other, it was ensured that both modules comprised the same content scope.

Standard Material—Noninteractive

The noninteractive e-learning module on COPD for the control group included an average of 5 bullet points per slide with several figures and tables (see Multimedia Appendix 2 for screenshots of the noninteractive module).

Interactive Material

The intervention group was provided access to a voice-over interactive e-learning module designed with iSpring Suite (see Multimedia Appendix 3 for screenshots of the interactive

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module) [40]. The interactive module was composed of a simple interactive environment that allowed the user to control the representation of information and receive predetermined feedback on activities [9]. In more detail, the interactive module included the following items sorted from representation control to obtaining feedback: interactive interfaces including drag and drop options; interactive X-ray images to be explored with the curser; a puzzle; a 10-step virtual patient, including different question paths representing a typical COPD exacerbation case; and 3 short multiple-choice quizzes, for which participants received feedback. Furthermore, the principles of adult learning by Taylor and Hamdy [41] were incorporated into the module. For example, the learner had to complete certain tasks several times, which challenged existing knowledge on COPD and might have put the learner in a *dissonance phase* as existing knowledge might have been incomplete. This *dissonance phase* was followed by a *refinement phase* in which the learner received information on the problem's solution.

Outcome Measures

Overview

The primary outcome was learner satisfaction based on a comparison of interactive and noninteractive e-learning modules. The secondary outcomes were system usability and short- and long-term knowledge gain. After study initiation, an outcome was added—identified barriers to asynchronous e-learning—as feedback from participants revealed usability issues. These end points were determined quantitatively with questionnaires using a web-based survey tool and qualitatively by 2 rating conferences conducted via Zoom [42-44].

Quantitative

The usability, including internet use and comprehensibility of the questionnaires in the web-based survey tool, was tested by a local study team member before study onset, and changes were made accordingly [43]. The user satisfaction questionnaire contained 8 questions on a 5-point Likert scale displayed on 1 page; therefore, 40 points were achievable in the overall user satisfaction. The usability of the modules was tested according to the System Usability Scale (SUS), a validated usability score from 0 to 100, in which 68 could be interpreted as an average according to a curved grading scale [44]. The two knowledge gain tests assessing short- (knowledge gain test 1 [KT1]) and long-term (knowledge gain test 2 [KT2]) knowledge gain were composed of 15 multiple-choice questions, where each question counted as 1 point. The knowledge questionnaires displayed 1 question per page, resulting in 15 pages per test. The knowledge questions were all answerable with the presentation and partly derived from questions of German medical exams because questions on COPD from previous Zambian medical exams were not available. The answers could be reviewed and changed with the back button. All questions in web-based questionnaires had to be completed to submit the results. The questionnaires can be found in Multimedia Appendix 4.

Qualitative

When assessing a teaching intervention, qualitative data from rating conferences can shed light on the quantitative findings. This method is based on school quality assessments. The results of quantitative evaluation data are displayed to a representative group of up to 12 students, and the following discussion provides in-depth insight into individual motivations and opinions of the participants [42].

Quantitative Evaluation

With the support of local study team members (AS and PA) and the local study coordinator (MM), the principal investigator (ES) conducted recruitment, randomization, and actual implementation of the trial from Germany. This was possible, as everything was conducted on the web because of the COVID-19 pandemic.

Recruitment and Randomization

All eligible students were invited to participate via email on April 20, 2021, and recruitment continued until April 30, 2021 (see Multimedia Appendix 5 for the study information sheet). Email addresses were obtained from the ML course coordinator (AS). Compensation for study participation and internet use related to the study were airtime vouchers, with a value of 200 Zambian Kwacha (US $10.9), to be received at the end of the entire study period.

Students willing to participate sent informed consent via email. Afterward, all participating students were equally randomized into the intervention and control groups using the random number function in Excel (Microsoft Corporation) and a blocked randomization list with a block size of 2 participants [45].

Participants were informally blinded to their group allocation for the first part of the study, as it was not stated in the information sheet which e-learning methods were being compared.

Phase 1: Evaluation of Satisfaction, Usability, and Short-term Knowledge Gain

Following randomization, the participants were invited on May 1, 2021, to participate in their respective e-learning module that was accessible using their e-learning platform account. The e-learning module could be studied asynchronously with the e-learning platform and application. Study participants only had access to their respective e-learning modules. Participants were informed that completing the e-learning module and filling the questionnaires would take approximately 45 minutes, but no time limit was set. Participation reminders were sent on May 7, 11, and 20, 2021, and through local study team members by class representatives. The e-learning platform was down for a few hours on May 4 and 7, 2021, but participants were given until May 31, 2021, to complete these tasks. It was possible to contact the principal investigator via email and a local study coordinator during the entire study. In the case of nonsolvable technical difficulties with the e-learning platform or the internet, individual students were sent a link to their respective e-learning module that was uploaded onto the cloud, whereas students in the control group received a PDF file [46]. The latter was not possible for students in the intervention group, as the interactive presentation could not be saved as a PDF file. Study participants receiving the cloud link or PDF file were asked not to share the information with other participants.

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After finishing the module, each participant was directly invited to complete the user satisfaction, SUS, and KT1 questionnaires on the web [43]. Participants stated their study ID in web-based questionnaires to protect personal data. They were asked not to use the presentation or any other additional help to answer the questions. As their log-in information to the e-learning module was not verified, participants were considered to have completed their respective e-learning modules by filling out the web-based questionnaires.

Participants who dropped out of the study because they could not complete phase 1 were labeled *initial study dropouts*, whereas participants who completed it were *first-part participants*. First-part participants were categorized as *early responders* if they completed the module directly or after 1 reminder and as *late responders if* they completed the module and survey after 2 or more reminders.

Phase 2: Evaluation of Long-term Knowledge Gain

Four weeks after phase 1, on June 28, 2021, the first-part participants were invited to complete the KT2 [43]. They were asked not to use the e-learning module or any other resource for help.

Data Extraction

Pseudonymized data from the web-based questionnaires were automatically transferred to an Excel spreadsheet, thereby maintaining data integrity and security, and then prepared for statistical computing.

Analysis

Overview

Statistical analysis of the quantitative data was performed using the programming language R (version 4.0.3; R Foundation for Statistical Computing) and the packages *psych* and *likert* [47,48]. A P value <.05 was considered statistically significant. Cohen d was assessed using a web-based tool, and a post hoc power analysis was calculated with the program G*Power (version 3.1; Erdfelder, Faul, and Buchner) [49].

Characteristics of Study Participants

Only participants who completed the web-based questionnaires and therefore were considered to have completed their respective e-learning module were analyzed for primary and secondary outcomes, resulting in a modified intention-to-treat analysis. Characteristics of first-part participants and initial study dropouts, as well as characteristics of rating conference participants, were compared using a 2-tailed t test and responding chi-square tests.

Quantitative Comparison of the Two Modules

Differences in questionnaire results between the intervention and control groups were evaluated using the Mann-Whitney U test. The difference between the two knowledge gain tests' scores of each group was calculated using a paired Wilcoxon test.

Factors Influencing Satisfaction, Usability, and Knowledge

We used linear regression, the Mann-Whitney U test, and the Kruskal-Wallis test to analyze whether several factors influenced overall user satisfaction, system usability, and knowledge gain test scores. If a factor with >2 subgroups, such as study year (second, third, and fourth), had a statistically significant influence on the questionnaire result, multiple pairwise comparisons were calculated using the R-function *pairwise.wilcox.test*.

Qualitative Evaluation

Overview

ES recruited rating conference participants by email and acted as a moderator. Before the study commenced, she had no relationship with the rating conference participants. Additional participants present were 4 extra study team members, including AB and FN, for transcription purposes. They took field notes and audio recordings, which ES later used for transcription.

Recruitment

Approximately 2 weeks after the first study period, on June 16 and 17, 2021, a total of 2 rating conferences took place via Zoom. More than half of the first-part participants (24/41, 59%) were invited to receive sufficient data saturation. Participants in the rating conferences were purposively sampled to be representative of the overall study population that completed the first part of the study. The purposive sampling was stratified for each allocation group according to sex, time of participation (early responder and late responder), and age (<25 years and >25 years), as the mean age (24.3, SD 4.8 years) of first-part participants was approximately 25 years. Rating conference participants received an additional airtime voucher (200 Zambian Kwacha) as compensation.

Phase 3: Conducting the Rating Conferences

Quantitative results from the web-based questionnaires were presented in the rating conferences, which lasted 60 minutes each. The following discussion was semistructured into four parts: satisfaction, usability, knowledge, and e-learning. Each subpart commenced with open questions from the moderator and probes, where appropriate. The semistructured interview guide was not pilot-tested; it was, however, internally reviewed, and a final version was agreed upon by the research team. An active discussion among all participants of the rating conferences was encouraged.

Analysis

The principles for coding and analyzing data were determined in advance. The determined codes and themes were not dependent on their prevalence in the entire data set but rather established through salience in the data. The analysis focused on a detailed description of the data using inductive data-driven analysis. Semantic rather than latent themes were identified, and finally, the analysis was approached in a realist manner, implying what was said was directly linked to its meaning [50]. The data were analyzed using thematic analysis, according to Braun and Clarke [50]. FR and ES examined the data set and identified codes and themes, which were structured into a preliminary coding tree using the NVivo program (version 12; QSR International). The coding tree was then finalized through continuous review of the data set, codes, and themes and an ongoing discussion between the two researchers responsible for

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data analysis. Afterward, the final coding tree was used by both researchers independently to code the data set again, and any discrepancies were discussed collaboratively. The final coding tree consisted of the following structure: the comparison of the e-learning modules regarding satisfaction, usability, and knowledge, access to the e-learning material, opinions on e-learning and improvement suggestions, and study limitations.

Results

Quantitative Evaluation of Phases 1 and 2

Characteristics of Study Participants

In total, 202 ML students, predominantly in their second year of study, were identified as eligible for participation. Of these, 47% (94/202) of the students signed up for the study. Ultimately, 44% (41/94) of these students participated in the first part of the study and were analyzed. The participant flow and reasons why enrolled participants did not complete the e-learning module and questionnaires (initial study dropouts) are shown in Figure 1. If a student had filled out the web-based questionnaire, it was assumed that they had also received their allocated intervention or control. In all, 2 students in the intervention group later reported in the rating conference that they had switched groups; however, a post hoc sensitivity analysis that excluded these 2 students revealed no differences in the outcomes. The KT2 was completed by 39 first-part participants, as 2 students were lost to follow-up. All participants who started filling out web-based questionnaires also completed them.

Table 1 shows the characteristics of first-part participants, initial study dropouts, and first-part participants in intervention and control groups. There were significantly more female students that were enrolled but did not complete the first part of the study. Apart from that, characteristics did not differ significantly.

Figure 1. CONSORT (Consolidated Standards of Reporting Trials) 2010 flow diagram. KT1: knowledge gain test 1; KT2: knowledge gain test 2; SUS: System Usability Scale; US: user satisfaction.

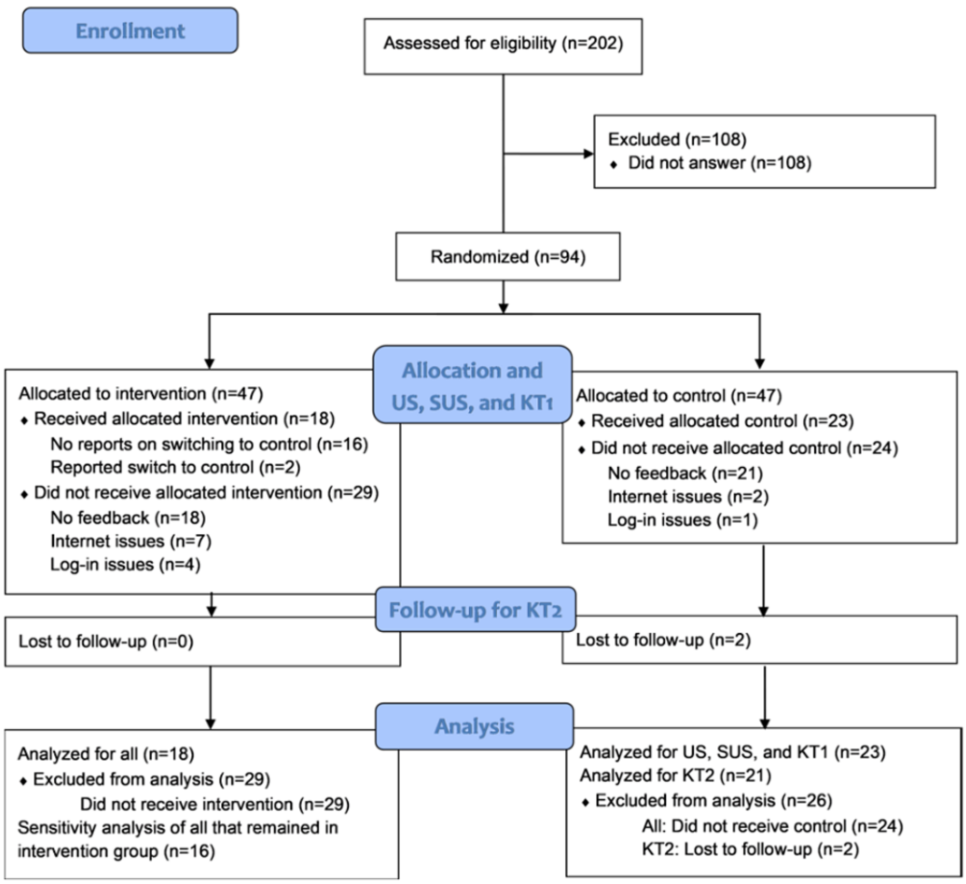

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Table 1. Characteristics of first-part participants, initial study dropouts, and first-part participants in intervention and control groups.

Characteristics	First-part participants (n=41)	Initial study dropouts (n=53)	*P* value	Intervention (n=18)	Control (n=23)
Age (years), mean (SD)	24.3 (4.8)	23.4 (5.4), n=40	.44	23.6 (3.5)	24.9 (5.7)
Sex (female), n (%)	14 (34)	34 (64)	.007	6 (33)	8 (35)
Group (intervention), n (%)	18 (44)	29 (55)	.41	N/A[a]	N/A
Study year, n (%)			.53		
2	29 (71)	40 (75)		14 (78)	15 (65)
3	5 (12)	8 (15)		2 (11)	3 (13)
4	7 (17)	5 (9)		2 (11)	5 (22)

[a]Not applicable.

Quantitative Comparison of the Two Modules

Primary Outcome: User Satisfaction

Results for user satisfaction were not statistically different between the intervention and control groups (Table 2). Bar plots of each user satisfaction question result for both groups are shown in Figure 2. Figure 3 depicts, among other things, the overall user satisfaction scores of the intervention and control groups in a box plot.

Table 2. Questionnaire results.

Parameters	Intervention (n=18)	Control (n=23)	*P* value
User satisfaction (n=41), median (Q1,[a] Q3[b])	33.5 (31.3, 35)	33 (30, 37.5)	.66
System Usability Scale (n=41), median (Q1, Q3)	65 (50.6, 76.9)	70 (57.5, 76.3)	.36
KT1[c] (n=41), median (Q1, Q3)	5.5 (4, 9.3)	7 (5, 9)	.26
Self-reported time for e-learning module (minutes; n=41), median (Q1, Q3)	51.5 (45, 60)	55 (40, 63)	.92
KT2[d] (n=39), median (Q1, Q3)	6 (3, 7)	6 (3.3, 7.8)	.88
KT[e] difference (test 1-2), n=39, median (Q1, Q3)	0.5 (−2, 3)	0 (−1, 5)	.58

[a]Q1: first quartile.

[b]Q3: third quartile.

[c]KT1: knowledge gain test 1.

[d]KT2: knowledge gain test 2.

[e]KT: knowledge gain test.

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Figure 2. Results of user satisfaction questions of the intervention and control groups in percent. Q1: I enjoyed the module. Q2: I am satisfied with the module. Q3: My COPD knowledge increased significantly. Q4: My interest in COPD increased. Q5: Module's key messages were clear. Q6: Module is relevant for medical practice. Q7: It was easy to learn with the module. Q8: I would recommend the module to a friend. C: control; COPD: chronic obstructive pulmonary disease; I: intervention Q: question.

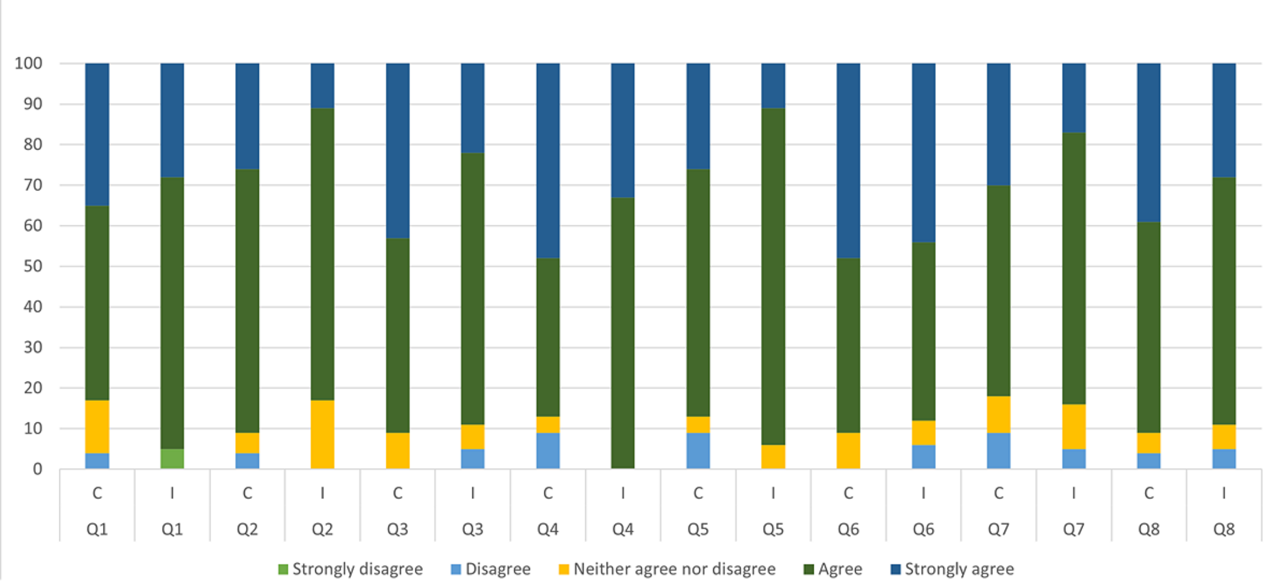
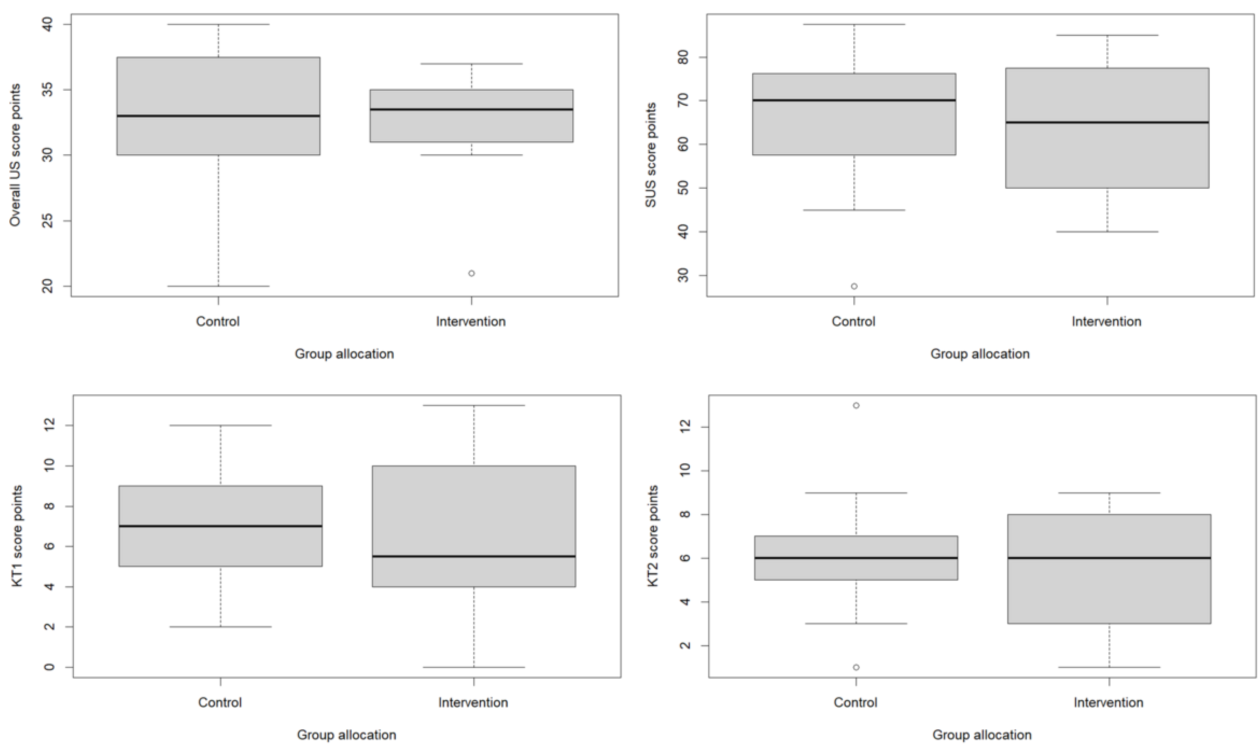


Figure 3. Box plots of different questionnaire results of the intervention and control groups. Box plots show median, first quartile, third quartile, minimum, maximum, and outliers. KT1: knowledge gain test 1; KT2: knowledge gain test 2; SUS: System Usability Scale; US: user satisfaction.



Secondary Outcomes: Usability and Knowledge Gain

The SUS and KT1 scores and self-reported time spent learning with the e-learning module did not differ statistically significantly between the intervention and control groups (Table 2). However, the data indicated that the intervention group stated slightly lower system usability and received a slightly lower KT1 score. In addition, there were no statistically significant differences in the KT2 and knowledge test scores between the two groups. The sample size for these 2 analyses was 39, as 2 participants were lost to follow-up. Furthermore, each group had a knowledge test score difference close to 0, and the analysis also confirmed that the KT1 and KT2 scores of each group were not significantly different. Figure 3 shows the different

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questionnaire scores of the intervention and control groups in boxplots.

Factors Influencing Satisfaction, Usability, and Knowledge

The influence of the following factors on user satisfaction, SUS, KT1, and KT2 scores was evaluated: additional study resources, age, device, participant environment, response time for study participation, sex, study year, and time spent learning (Table 3). The influence of the study year on the SUS score was statistically significant. Further analysis revealed a significant difference in SUS scores between second- and fourth-year students, and fourth-year students correlated with a higher SUS score. In addition, a significant correlation was found between the study year and KT1 score. However, when testing for multiple pairwise comparisons to further determine which study years differed significantly in their KT1 scores, no statistically significant differences were found. Most likely, the difference in KT1 score between the second and third study years caused the overall significant correlation, as third-year students had a higher median KT1 score than second-year students, and the *P* value of that combination was the lowest at .06.

Table 3. *P* values of correlations between different factors with questionnaire results.

Factors	US[a] (n=41)	SUS[b] (n=41)	KT1[c] (n=41)	KT2[d] (n=39)
Sex	.48	.37	.52	.48
Age	.45	.24	.85	.39
Study year	.17	.04	.03	.11
Response time	.08	.93	.88	.57
Environment	.20	.35	.76	.71
Device	.27	.44	.19	.11
Other resource	.25	.08	.07	.41
Time	.29	.15	.06	.49

[a]US: user satisfaction.
[b]SUS: System Usability Scale.
[c]KT1: knowledge gain test 1.
[d]KT2: knowledge gain test 2.

Qualitative Evaluation of Phase 3

Characteristics of Study Participants

We invited 24 first-part participants to participate in the rating conferences (see *Methods* for sample size and recruitment procedures), of whom 54% (13/24) replied and participated in 2 rating conferences. Table 4 shows the characteristics of all rating conference participants and the rest of the first-part participants and the characteristics of both rating conference groups. No statistically significant differences were found among groups.

Table 4. Characteristics of rating conference participants versus other first-part participants and rating conferences.

Characteristics	Rating conference participants (n=13)	Other first-part participants (n=28)	*P* value	Rating conference 1 (n=7)	Rating conference 2 (n=6)	*P* value
Age (years), mean (SD)	26 (6.9)	23.5 (3.4)	.24	26 (6.1)	26 (8.3)	.99
Group (intervention), n (%)	8 (62)	10 (36)	.23	4 (57)	4 (67)	.99
Sex (female), n (%)	4 (31)	10 (36)	.99	3 (43)	1 (17)	.68
Study year, n (%)			.67			.88
2	8 (62)	21 (75)		4 (57)	4 (67)	
3	2 (15)	3 (11)		1 (14)	1 (17)	
4	3 (23)	4 (14)		2 (29)	1 (17)	

Qualitative Results

In addition to their own views, participants also relayed the views of other participants absent in the conference as they had communicated with other study members. As the results of these 2 perspectives did not differ, they are presented together.

Primary Outcome User Satisfaction and Secondary Outcome Usability

Students often reported that it was their first time learning about COPD and expressed gratitude for the opportunity. Comparing the two e-learning methods, satisfaction and usability were linked and, therefore, assigned a category together. Participants reported challenges in accessing both e-learning modules, resulting in lower satisfaction:

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> *I think it really affected my happiness because I don't like ending things halfway or something taking that long.* [Participant 7, control, female]

The noninteractive module took a long time to load and sometimes just crashed while viewing the presentation; however, access to the interactive module seemed to be impeded even more as a few students from that group (3/8, 38%) reported that they were not able to finish learning with it or could not access it at all:

> *I was not able to get into anything.* [Participant 5, intervention—changed to control, male]

In addition, the interactive software was described as challenging to use once having gained access to it. This was mainly because of technical difficulties, as it was reported (4/8, 50%) that going back and reviewing the interactive e-learning module was difficult, and the graphics were poorly presented on students' phones.

These access challenges using the interactive module led to intervention participants using alternative methods to learn about COPD. Further research on the web (2/8, 25%) or gaining access to the e-learning module of the noninteractive group (2/8, 25%) were reported:

> *I failed to use the interactive instead I managed to access the non-interactive.* [Participant 5, intervention—changed to control, male]

An explanation of how access to the noninteractive e-learning module was achieved was not given by the participants in question. An additional challenge for students in the intervention group was the limited e-learning experience with interactive e-learning:

> *Some people [said]: 'ah I gave up' after trying to use it.... Because some of them it was the first time having to use that interactive session. So, some of them didn't even know they had to actually click some of those things.* [Participant 9, intervention, male]

A few students (2/8, 25%) reported that they would have preferred the noninteractive e-learning module because it was simpler, and the interactive e-learning module was deemed complicated:

> *I thought like it was a little bit clustered [cluttered]. Like I actually had to search around and see where exactly I have to go back to. So yeah otherwise, other than that I would have actually even preferred to have the PowerPoint one.* [Participant 9, intervention, male]

However, other students (3/8, 38%) declared being satisfied with the interactivity of the intervention module, as "it's like you are having your lecturer right there" (participant 12, intervention, male). They enjoyed "the imagery parts where you could actually click on things" (participant 10, intervention, male).

Furthermore, rating conference statements showed that there was no gender dimension regarding access to interactive e-learning, and female and male participants struggled to access the interactive module alike.

Secondary Outcome Knowledge Gain

Both groups regarded the knowledge gain test's difficulty as adequate. Nevertheless, there was a discrepancy between the participants' views of its feasibility and the overall outcome. When confronted with the results, some participants (5/13, 39%) viewed the impeded access to the e-learning modules as the reason for the average marks of both groups:

> *I think the reason why the performance was average is probably because maybe the majority were not able to finish their modules, so I guess.* [Participant 6, control, female]

Nonetheless, more members of the interactive group (4/8, 50%) linked their increased barriers in accessing and using their e-learning module with their reduced knowledge gain test results:

> *I feel that the ones that had the control maybe they had a slightly easier way of going back to certain things that they had to read over.... I think if people had more experience to actually go back to the interactive sessions, I think there would have been better marks than that.* [Participant 9, intervention, male]

Secondary Outcome Barriers to e-Learning

A few barriers to access the e-learning material are mentioned above; however, the following results provide a more comprehensive overview. Figure 4 depicts the identified barriers, which can be divided into technical and individual barriers. Technical barriers identified were limited access to digital devices compatible with the e-learning platform, technical challenges with the e-learning platform, including log-in and the e-learning software itself, and internet access. Determined individual barriers occurred because of the limited e-learning experience of participants. These included limited knowledge on logging in to Moodle, using the e-learning platform and the software of the e-learning modules, and problem solving if a technical issue occurred. The difference between technical and individual barriers was that individual barriers were user generated.

A student reported that the tablets that were initially distributed when the e-learning program was implemented were not being used by him or by some of his fellow students. The reason was that the device "just lags and then it will fail to load" (participant 9, intervention, male). In addition, students (4/13, 31%) reported that access to other suitable electronic devices was difficult for some participants:

> *Yes, they did have smartphones, but not the ones that would load the e-learning module.* [Participant 12, intervention, male]

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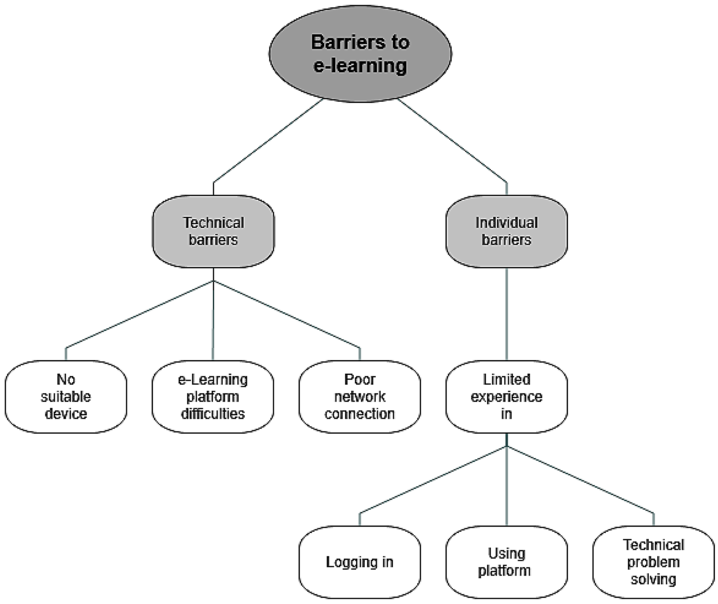
Figure 4. Barriers to e-learning.



Some students encountered technical challenges when trying to log in to the e-learning platform (2/13, 15%), as they could not generate new passwords themselves:

> *It took me quite a, I think a few days. I had to actually get in touch with the HIGH IT personal from the university to actually help me with my username and my password.* [Participant 9, intervention, male]

When fellow students of this particular participant heard that he was able to log in, they "were actually shocked to say how did you manage?" (participant 9, intervention, male).

Furthermore, the software of the e-learning modules was considered a barrier in various ways. Participants often reported that the modules were "taking long to load" (participant 12, intervention, male) or that the system "just froze...it didn't have anything to do with the network" (participant 7, control, female). Once they had gained access to the e-learning materials, some participants (4/13, 31%) stated difficulties in going back in the presentation or viewing the graphics on their phones. This was mainly the case for the interactive e-learning modules. Often, study participants (5/13, 39%) reported that difficulties vanished when using a larger electronic device, such as a laptop or desktop computer:

> *So I had the same experience when I used my phone, but when I switched to the PC it was like working.* [Participant 12, intervention, male]

> *I needed to use a laptop I think for me to have access.* [Participant 1, intervention, male]

Participants (5/13, 39%) stated that the internet connection posed another barrier to accessing the e-learning modules. The connection had to be fast, loading the modules took a long time, and some students were located in areas with very limited internet access. When asked why there were so many study dropouts, a participant replied the following:

> *For the people that I got to ask, one of them was in an area that had really horrible network. So, she only got the email like time after the whole participation thing had passed. So maybe the main reason was that everything had network issues and maybe things were not syncing or loading as fast as some people, because they were in a different area.* [Participant 7, control, female]

The use of the e-learning platform Moodle, and consequently students' e-learning experience with it, was reported to be low. Other methods of web-based learning, although not asynchronous, were used during the COVID-19 pandemic:

> *We once tried to use Moodle at the school, but it never worked out, so we switched to Zoom or Google Meet.* [Participant 12, intervention, male]

This limited experience frequently impeded participants' access as they forgot their e-learning platform log-in details and had restricted knowledge about the e-learning platform and software or technical problem solving if an issue emerged:

> *So, others had forgotten how to use it. So, I find instead of putting their username, they were putting in the email address with the correct password. So, they were failing to login.* [Participant 1, intervention, male]

> *Most of the people that we have in our class haven't used the e-learning modules or used Moodle. So, they had challenges with navigating through.* [Participant 9, intervention, male]

Opinions of e-Learning and Suggestions for Future Improvement

It was evident that, despite the access challenges, students' motivation and their opinions regarding e-learning were positive, especially in a pandemic context:

> *I think it's actually a good development. And I think it would help, especially in this time where we are actually battling with Corona. It would actually help. And then it gives you also a chance to actually do it at your own time and you don't feel rushed. So, you*

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> *actually prepare for it.* [Participant 9, intervention, male]

However, it was also mentioned that asynchronous e-learning was fairly difficult and lacked interaction with teachers (5/13, 39%):

> *It would have been better if there was someone explaining it.* [Participant 7, control, female]

A student's opinion was that e-learning "can work as a backup where physical learning is not possible due to limited space or as a way of revising with students" (participant 11, control, male).

Finally, participants gave several suggestions for improvement, such as developing an e-learning software compatible with their phones or otherwise access to suitable gadgets, improving the log-in to the e-learning platform, and using more e-learning, which should also be more standardized in its presentation:

> *And I think with a little bit more usage I think I would get experience in terms of how to really navigate it well and yeah. I think that's the issue. I think using it more and not having issues with the logging in, I think would really, really help.* [Participant 9, Intervention, Male]

> *I just feel like if it could be more consistent just for people to get a grip of it that would be nice.* [Participant 8, control, male]

Discussion

Comparison of Interactive Versus Noninteractive e-Learning

Primary Outcome User Satisfaction and Secondary Outcome Usability

Principal Findings and Explanations

In contrast to the initial hypothesis derived from studies on HICs, there were no significant differences among the groups in the primary outcome of user satisfaction in this low-resource setting [13,14,18,19]. This suggests that both modules were received similarly. The overall user satisfaction in both groups was acceptable. The median SUS score of both modules was assessed as average. Furthermore, there was no significant difference in SUS scores between the two modules, implying that both were equally challenging to use. However, contrary to the quantitative data, qualitative data showed that the interactive e-learning module had lower usability than the noninteractive module. The interactive module was harder to access, as multiple students could not finish it, it was not correctly displayed on the phones, and revising it was difficult. The interactive module was also harder for some students, as they were not familiar with interactive e-learning. Qualitative data also indicated that usability challenges negatively influenced students' satisfaction with the modules, thereby linking these 2 distinct outcomes. There are several possible explanations for the lack of differences in user satisfaction between the two groups.

A reason could be an insufficient number of study participants to show an effect. Owing to many dropouts, the size of the analyzed population was limited. Furthermore, the difference in user satisfaction between both groups was small, and a post hoc power analysis revealed a low power of 7%, leading to the conclusion that quantitative data might be insufficient to prove or disprove the assumed hypothesis.

Another reason could be that the increased usability issues of the interactive module may have had a negative effect on the user satisfaction rating, as indicated by the qualitative data. Gunesekera et al [51] conducted a literature review that supports this assumption on the relationship between usability and satisfaction. Better usability results in a higher motivation to learn [52]. Nevertheless, the correlation is not as simple as it seems. Davids et al [53] conducted a study in South Africa using a similar approach. However, they compared their original interactive e-learning module with a revised version in which all usability issues were addressed. Yet, comparable with this study, there were no significant differences in satisfaction, usability, and knowledge gain between the two groups. When analyzing the objective usability through a video of the study, however, there were significantly fewer problems in the intervention group, resulting in objective usability differences among groups. When assuming that there were indeed usability differences but no user satisfaction differences between the two groups, the results of Davids et al [53] contradict the conclusion of the literature review by Gunesekera et al [51].

Another explanation for the lack of quantitative difference in satisfaction between the two groups could be that the participating students were more familiar with traditional teaching methods and less familiar with interactive e-learning than students in HICs [7]. Consequently, this could impede the rating of satisfaction and usability of interactive materials. The qualitative data of this study further supports this interpretation, as some participants in the intervention group were overwhelmed with the interactive technology or preferred the noninteractive presentation because it was simpler, possibly because of a lack of experience with interactive e-learning. Additional evidence for this was that fourth-year students rated the usability of their e-learning modules significantly higher than second-year students. They might have been exposed to e-learning technology longer and therefore found it easier to use.

Finally, as the 8 user satisfaction questions selected were not validated, they may not have accurately portrayed user satisfaction.

Comparison With Previous Work

When considering these results in context with the existing literature, studies with similar findings are rare. Nevertheless, most studies use distinct tools to assess user satisfaction, which limits comparisons. For the most part, studies that compared the user satisfaction of interactive and noninteractive e-learning for health care personnel demonstrated results in favor of the interactive e-learning method [13,14,18,19,54]. However, they were mostly conducted in HICs. Koka et al [14] provided an example of this. Their study was conducted in Switzerland and showed that paramedics undergoing an interactive e-learning

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module had increased knowledge of the National Institutes of Health Stroke Scale and higher satisfaction with the learning method than paramedics watching a video of the same learning content [14]. Another example is the RCT implemented by Lee et al [19] in Taiwan. In this study, undergraduate medical students were randomized to receive an interactive multimedia module or PowerPoint presentation slides. Although no significant difference in knowledge gain was observed among groups, the intervention group received significantly higher user satisfaction scores [19]. Nevertheless, there are studies that, as this study, show no difference in user satisfaction, comparing interactive with noninteractive e-learning [55,56].

Overall, the results of this study invoke the question of whether ease of use is a more important factor for user satisfaction than content presentation. Given that this study's findings differed from the conclusions of similar studies in HICs, they further raise the question of equity in access to knowledge and education via e-learning in LMICs.

Secondary Outcome Knowledge Gain

Principal Findings and Explanations

Both groups received low to average KT1 and KT2 scores. This could indicate that both e-learning modules were not able to convey as much information as expected. However, another possibility is that the knowledge tests did not measure the true knowledge as they were not validated.

An additional finding of this study was that there was no significant difference between the KT1 and KT2 scores of each group. Assuming that both knowledge tests were equally challenging, this indicates that there was no significant knowledge loss after 6 weeks for both groups. This result could be interpreted as an advantage for both e-learning courses. However, it was not compared with a group that only received traditional classroom teaching, for example, and therefore cannot be contextualized.

Contrary to other studies, the analysis of this work also revealed no significant difference in short- or long-term knowledge gain between the two groups [13-18]. This was potentially related to qualitative data, which indicated that impeded access to the interactive e-learning module made it harder for students in the intervention group to learn the material or even look up information during the knowledge test. Participants were told not to use any material to help answer the knowledge questions; however, this was not verifiable.

Comparison With Previous Work

There have been several RCTs, including the one by Koka et al [14] that postulate interactive e-learning increases knowledge better than noninteractive e-learning. However, they were all conducted in HICs. Velan et al [17] showed in a randomized crossover trial that interactive e-learning modules were significantly more effective in improving medical students' knowledge about the adequate use of imaging than PDF-based modules. DeBate et al [15] compared an interactive e-learning module for secondary prevention of eating disorders using a flat-text e-learning module in an RCT. They concluded that the interactive module was better at improving students' skill-based knowledge and self-efficacy but not overall knowledge [15]. Morgulis et al [16] demonstrated in an RCT that an interactive e-learning module significantly increased knowledge about leukemia better than existing web-based resources in senior medical students.

However, it seems that the hypothesis does not always hold true. Apart from the RCT by Lee et al [19], other studies provide additional examples. Suppan et al [55,56] conducted 2 web-based RCTs with student paramedics and emergency medicine personnel in Switzerland. The intervention group received a gamified e-learning module about personal protective equipment for COVID-19, whereas the control group received flat-text COVID-19 guidelines for prehospital emergency medicine use. The primary end point was the difference in postintervention knowledge between the two groups, and, as in this study, it was not statistically significant. Another study conducted with Canadian medical students compared an interactive e-learning module on global health with PDF articles on the same topic. Although participants' satisfaction with the interactive module was higher, no difference in postintervention knowledge was detected [54].

Barriers to e-Learning

Principal Findings and Explanations

There were 56% (53/94) of study dropouts, possibly because of problems accessing the e-learning modules. The identified barriers to e-learning were of a technical and individual nature. Technical barriers included limited access to suitable electronic devices and difficulties with the e-learning platform, including log-in and software issues (eg, long loading times, crashing, and poor graphics presentation). An additional technical barrier was insufficient internet access. The e-learning platform can also be used via an application that would have probably increased the technical usability; however, this was possibly not known to all study participants. Because of the COVID-19 pandemic, the small information technology (IT) support team at LMMU was overwhelmed by many tasks when participants needed access to the e-learning platform. This may explain the insufficient capacity to instruct all students before the study. Individual barriers may be summarized as limited *e-learning culture* owing to low e-learning use and encompassed restricted e-learning experience in logging in to the e-learning platform, using the e-learning platform and software, and technical problem solving if technical issues occurred. In addition, the lack of communication with teachers was often viewed as having a negative impact. Among the study dropouts, there was a significantly higher number of female students, which may indicate that this student group was more affected by these barriers. A possible reason could be inadequate technology experience, as a questionnaire in 2017 indicated that female ML students had low technology experience, whereas male ML students had moderate experience [23].

It is assumed that had this study been conducted on campus, some of these hindrances, especially regarding the e-learning infrastructure (suitable devices and internet), could have potentially been avoided. However, because of the COVID-19 pandemic, participants had limited access to facilities at the LMMU campus.

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Comparison With Previous Work

Most of the identified barriers, such as poor e-learning infrastructure, including device and internet availability or insufficient interaction with a teacher, are well known in the literature on e-learning in LMICs, and some are known from previous studies at the LMMU [1,4,22]. An example is a survey in the Philippines that assessed barriers encountered by medical students when trying to learn on the web after the COVID-19 pandemic had just hit. Identified barriers also included limited access to electronic devices and the internet. However, students also struggled to adapt to the new learning method [57]. This may suggest that, as in this study, some barriers to e-learning in LMICs are set beyond the technical infrastructure, as they might also be dependent on the individual characteristics of e-learning students. These individual barriers may be inherent to nascent e-learning systems in a low-resource context.

e-Learning Use

Barteit et al [22] assessed e-learning platform use as low in 2017. Unfortunately, this appears unresolved, as some participants reported that they did not use the e-learning platform to study. Furthermore, most students had e-learning platform accounts but had not used them regularly, so some had forgotten their log-in details. Explanations for this low use are difficult to discern because of the various stakeholders involved in an e-learning system. In 2017, reasons included the low quality of the tablets, insufficient e-learning training for students and lecturers, and average quality of the e-learning material, with low motivation of teachers to update and improve the content [22]. As the aims of this study did not include the evaluation of the use of the e-learning platform, only assumptions can be made for low use. Several factors should be considered to promote e-learning use in a low-resource context, some of which may be applied insufficiently at the LMMU: up-to-date information should be conveyed in the e-learning material, the practicality of e-learning should be advocated while e-learning services should be expanded, e-learning should be user friendly, sufficient technology training should be provided to students and lecturers, and individual motivation toward e-learning should be increased to promote overall e-learning use [7]. The IT resources during the implementation of this study were strained, meaning there may be insufficient IT resources to promote these factors to increase e-learning use at the LMMU.

Strengths and Limitations

This study is the first to compare interactive and noninteractive e-learning for students in clinical sciences or comparable studies in Zambia and one of the first known in a lower-middle–income country. As the value of e-learning in low-resource countries is increasingly recognized, especially during the COVID-19 pandemic, it is important to assess different e-learning methods in these settings, and the mixed methods design of this study allowed a comprehensive overview of the subject. However, this study had several limitations. They can be structured into general study limitations, limitations associated with the web-based study format, and shortcomings of the e-learning module comparison.

The analyzed study sample might be biased because only users were evaluated and not the original sample (because of many dropouts). This also resulted in a small sample size of the analyzed population and low post hoc power. However, the sample still seems to represent the overall group of students in the ML course quite well. In addition, the principal investigator developed the e-learning content, which could have affected the results. Social desirability could have also influenced participants' statements in rating conferences, as the principal investigator was also a rating conference moderator. We attempted to circumvent this bias in qualitative data acquisition by repeatedly asking the participants for their honest opinions, building rapport, and probing for details.

Because of the COVID-19 pandemic, this study was conducted on the web, which poses further limitations. Recruitment was completed by email, which could have limited the number of students enlisted. Furthermore, insufficient internet access and connectivity may have affected the students' completion of the web-based questionnaires and communication in the rating conferences because of dialogue loss.

Qualitative data suggested that the interactive module was more difficult to access and use; therefore, the comparison of the two e-learning modules was likely limited by the experienced technical problems. In addition, some students gained access to the other e-learning module but were analyzed for their originally assigned module; however, a post hoc sensitivity analysis that excluded these 2 students showed no differences in the assessed outcomes. Finally, participants may have looked up answers on the web, done teamwork, or unblinded themselves through conversations with other participants. Although such behavior affects outcome variables, it is most likely a reflection of learning in real-world circumstances.

Suggestions for Further Research

Secondary results suggested that the current relevant question may not be interactive versus noninteractive e-learning at the LMMU but the ease of access to e-learning. Although students' motivation for e-learning was high, the e-learning program at the LMMU still faces several challenges. These can and should be addressed through further e-learning training for all students and lecturers and the promotion of continuous implementation of e-learning as an integral part of the curriculum. Increased use, in turn, would likely help improve the user experience of the e-learning platform. Additional resources should be allocated for IT personnel and infrastructure, if possible and needed. Future studies comparing interactive and noninteractive e-learning for health care personnel in low-resource settings such as Zambia should ensure that potentially limiting factors in the technical access to e-learning materials are mitigated. This could be achieved by uploading the study content for offline use to a set number of tablets. However, this would likely decrease external validity.

Conclusions

In contrast to previous studies conducted in HICs, interactive and noninteractive e-learning were not significantly different in terms of user satisfaction and knowledge gain. However, these results may not be generalizable to other low-resource

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settings because the post hoc power was low, and the e-learning system at the LMMU has not yet reached its full potential. Consequently, barriers to accessing e-learning, which were of a technical and individual nature, may have affected the results, particularly as the interactive module was deemed harder to access and use. The extent to which some limitations were inherent to the nascent e-learning system, as opposed to the result of impaired e-learning access, is difficult to assess. Future studies should minimize technical e-learning barriers to further evaluate interactive e-learning in LMICs.

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Authors' Contributions

FN initiated the study and conceived the research questions and study design. ES created the e-learning material; obtained consent from the ethics committees; and conducted the recruitment, randomization, implementation, and quantitative analysis of the trial with the help and supervision of FN, MM, AS, PA, SB, VRL, and GS. ABR guided the qualitative research, and FR and ES performed the qualitative analysis. All the authors contributed to the writing of the manuscript.

Conflicts of Interest

FN and SB participated in implementing the e-learning system at the Levy Mwanawasa Medical University in 2016 and 2017. In addition, the principal investigator developed both e-learning modules. This publication was supported by the Heidelberg Graduate School of Global Health, which is funded by the Else-Kröner-Fresenius-Stiftung. The study was conducted within the framework of the BLiZ (Blended Learning in Zambia) Project with a 2-fold focus on sustainability and long-term implementation (also funded by the Else-Kröner-Fresenius-Stiftung [project 2019_HA25]). The funder had no influence on study design, implementation, or publication.

Editorial Notice

This randomized study was not registered. The authors explained that they "worked solely with health care providers and not patients". The editor granted an exception from ICMJE rules mandating prospective registration of randomized trials because the risk of bias appears low and the study was considered formative, guiding the development of the application. However, readers are advised to carefully assess the validity of any potential explicit or implicit claims related to primary outcomes or effectiveness.

Multimedia Appendix 1
CONSORT-EHEALTH checklist (V 1.6.1).
[PDF File (Adobe PDF File), 796 KB - mededu_v8i1e34751_app1.pdf]

Multimedia Appendix 2
Screenshots of the noninteractive module [25,38,39].
[PDF File (Adobe PDF File), 1305 KB - mededu_v8i1e34751_app2.pdf]

Multimedia Appendix 3
Screenshots of the interactive module [25,38,39].
[PDF File (Adobe PDF File), 9736 KB - mededu_v8i1e34751_app3.pdf]

Multimedia Appendix 4
Questionnaires.
[PDF File (Adobe PDF File), 243 KB - mededu_v8i1e34751_app4.pdf]

Multimedia Appendix 5
Study information sheet.
[PDF File (Adobe PDF File), 183 KB - mededu_v8i1e34751_app5.pdf]

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Abbreviations

BLiZ: Blended Learning in Zambia
CHERRIES: Checklist for Reporting Results of Internet E-Surveys
CONSORT-EHEALTH: Consolidated Standards of Reporting Trials of Electronic and Mobile Health Applications and Online Telehealth)
COPD: chronic obstructive pulmonary disease
COREQ: Consolidated Criteria for Reporting Qualitative Research
GOLD: Global Initiative for Chronic Obstructive Lung Disease
HIC: high-income country
IT: information technology
KT1: knowledge gain test 1
KT2: knowledge gain test 2
LMIC: low- and middle-income country
LMMU: Levy Mwanawasa Medical University
ML: medical licentiate
RCT: randomized controlled trial
SSA: sub-Saharan Africa
SUS: System Usability Scale

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Original Paper

Learning Analytics Applied to Clinical Diagnostic Reasoning Using a Natural Language Processing–Based Virtual Patient Simulator: Case Study

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Abstract

Background: Virtual patient simulators (VPSs) log all users' actions, thereby enabling the creation of a multidimensional representation of students' medical knowledge. This representation can be used to create metrics providing teachers with valuable learning information.

Objective: The aim of this study is to describe the metrics we developed to analyze the clinical diagnostic reasoning of medical students, provide examples of their application, and preliminarily validate these metrics on a class of undergraduate medical students. The metrics are computed from the data obtained through a novel VPS embedding natural language processing techniques.

Methods: A total of 2 clinical case simulations (tests) were created to test our metrics. During each simulation, the students' step-by-step actions were logged into the program database for offline analysis. The students' performance was divided into seven dimensions: the identification of relevant information in the given clinical scenario, history taking, physical examination, medical test ordering, diagnostic hypothesis setting, binary analysis fulfillment, and final diagnosis setting. Sensitivity (percentage of relevant information found) and precision (percentage of correct actions performed) metrics were computed for each issue and combined into a harmonic mean (F_1), thereby obtaining a single score evaluating the students' performance. The 7 metrics were further grouped to reflect the students' capability *to collect* and *to analyze* information to obtain an overall performance score. A methodological score was computed based on the discordance between the diagnostic pathway followed by students and the reference one previously defined by the teacher. In total, 25 students attending the fifth year of the School of Medicine at Humanitas University underwent test 1, which simulated a patient with dyspnea. Test 2 dealt with abdominal pain and was attended by 36 students on a different day. For validation, we assessed the Spearman rank correlation between the performance on these scores and the score obtained by each student in the hematology curricular examination.

Results: The mean overall scores were consistent between test 1 (mean 0.59, SD 0.05) and test 2 (mean 0.54, SD 0.12). For each student, the overall performance was achieved through a different contribution in collecting and analyzing information. Methodological scores highlighted discordances between the reference diagnostic pattern previously set by the teacher and the one pursued by the student. No significant correlation was found between the VPS scores and hematology examination scores.

Conclusions: Different components of the students' diagnostic process may be disentangled and quantified by appropriate metrics applied to students' actions recorded while addressing a virtual case. Such an approach may help teachers provide students

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with individualized feedback aimed at filling competence drawbacks and methodological inconsistencies. There was no correlation between the hematology curricular examination score and any of the proposed scores as these scores address different aspects of students' medical knowledge.

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KEYWORDS

clinical diagnostic reasoning; learning analytics; natural language processing; virtual patient simulator; medical education; medical knowledge

Introduction

Background

Virtual patient simulators (VPSs) are didactical tools that require students to face a variety of clinical scenarios. Providing students with software-based medical training that may be integrated with in-person clinical internships can help them develop diagnostic skills [1-8]. Furthermore, through adequate metrics obtained from the analyses of the user's logged actions, VPSs may generate a multidimensional representation of the students' medical competence, thus providing teachers with potentially valuable didactical information [9-13]. VPSs may include the use of natural language processing (NLP) techniques to better mimic physician–patient interactions and facilitate the use of these techniques by medical school students [13-15].

In many VPSs, metrics are set up to merely assess sectorial aspects of the overall patient's diagnostic management, such as history taking [14] or clinical examination [13], whereas, in other VPSs, crucial diagnostic activities such as conducting a physical examination and ordering medical tests are not considered [15]. Therefore, many VPSs and their relative metrics aim to address specific didactical items rather than embracing the overall clinical diagnostic approach. The latter is crucial in undergraduate medical training as most diagnostic errors made by junior physicians are caused by flaws in data collection or data integration [15]. There is a need for novel VPSs that target all areas of the diagnostic process while maintaining the user-friendly features provided by NLP techniques.

In addition to VPSs, another technology that may potentially benefit medical education is the intelligent tutoring system (ITS) [9-13] as it provides students with ad hoc feedback on a step-by-step basis and provides proper remediation suggestions [16,17]. For example, the CIRCISM-Tutor [18] was created to teach first-year medical students blood pressure regulation concepts. The COMET algorithm [19] was applied to problem-based learning by incorporating multimodal interfaces with text and images. The StoichTutor [20] helped students learn stoichiometry, although its application was mostly restricted to high school teaching. From a didactical standpoint, these tools proved to be effective in helping students improve their skills by facilitating reasoning and promoting cognitive associations during the learning process [9-13,21,22]. However, in these cases, ITS technology was not applied to the entire clinical case simulation.

We recently developed a VPS, Hepius, which integrates ITS components [23] that address 2 main activities carried out by a physician when managing a patient: data gathering and data analysis. NLP techniques were used to mimic physician–patient interactions. Data gathering comprised four main components: (1) examination of patient information (ie, the input scenario) in a simulated electronic medical record, (2) medical history collection, (3) physical examination, and (4) diagnostic test order. The data analysis model entailed four main components: (1) hypothesis generation, (2) binary analysis, (3) pattern analysis, and (4) final diagnosis. Student data gathering and analysis performance were addressed and quantified by setting appropriate metrics and general learning analytics.

Objective

In this study, we describe the learning analytics obtained by tracking medical students' execution of 2 virtual patient simulations using Hepius. In particular, the results obtained from a group of fifth-year students attending the Humanitas University Medical School are presented and discussed in relation to their potential learning implications. Learning analytics obtained from the first simulation test are also preliminarily confronted with the scores obtained by the medical students on their hematology final examination.

Methods

Ethics Approval

In keeping with our Internal Review Board policy at Comitato Etico Indipendente IRCCS- Istituto Clinico Humanitas no ethics approval was applied for because this is a pedagogical research study, not a clinical study. Data were properly anonymized and informed consent was obtained from all participants at the time of original data collection. Finally, the study does not involve any potential risk of damage to the participants and is not associated with any side effect. A simple written communication was sent to the Internal Review Board, as requested.

Diagnostic Process Simulator Components

This section provides a synthetic description of the main features underlying Hepius's diagnostic model, which is necessary for the full comprehension of the learning analytics. A detailed description of the program is provided elsewhere [23].

Input Scenario

The student is provided with a brief text describing the patient's current complaint. In this phase, the student is expected to identify the relevant diagnostic factors contained in the text. A diagnostic factor is a piece of defined clinical information that may help reach a diagnosis (eg, the patient has a fever or Blumberg sign is positive).

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Medical History Collection

The student must collect further diagnostic factors by formulating questions as though interviewing a real patient. The Hepius NLP algorithm pipeline examines the input question and searches for matching answers (if any) in the question set prepared by the simulation author (ie, the teacher). If a match is found, the program displays the simulation question along with the corresponding answer. For example, if the student were to type *Do you have shortness of breath?* in the free-text dialog box, the NLP pipeline would look for a matching question in the simulated case database (eg, *Do you have dyspnea?*) and automatically provide the corresponding answer (eg, *Yes, I have*). This advanced NLP algorithm takes advantage of a previous NLP algorithm developed by our group to automatically identify patients with syncope from an administrative database [24].

Physical Examination

The student is requested to understand which physical examinations are relevant for that specific clinical case. The student has the possibility to either select from a drop-down menu or type in appropriate physical examinations in a free-text dialog box. The relevant examinations that should be performed have been previously determined by the simulation author. All relevant and irrelevant actions performed by the students can be tracked and measured.

Medical Test Request

The student may choose to order a diagnostic test. The task of requesting a test is performed in the same manner as the physical examinations. A test request is considered correct only if deemed relevant by the simulation author. When correct, the results of the test are provided.

Diagnostic Hypothesis

On the basis of the information collected during the previous phases, the student is expected to formulate 1 or multiple diagnostic hypotheses. This is done by inserting the hypothesis in natural language into a free-text dialog box. The NLP component of Hepius is responsible for matching the hypothesized diagnosis with the one selected by the simulation author as the most relevant hypothesis. This NLP component matches the student's description with the standard Systematized Nomenclature of Medicine–Clinical Terms (SNOMED–CT) description [25] that is saved in the simulation database. If the hypothesis formulated by the student exists in the list of reasonable diagnostic hypotheses set by the author, positive feedback is given, and the diagnostic hypothesis appears in the binary analysis.

Binary Analysis

The student is required to make correlations between all the identified diagnostic factors and the diagnostic hypotheses to improve the capability to analyze the gathered information and form connections. For each pair of diagnostic factor–diagnostic hypothesis relations, the student must decide whether a single diagnostic factor increases, decreases, or neither increases nor decreases (ie, it is neutral) the probability of that diagnostic hypothesis. The binary analysis is a simplified form of the script concordance test (SCT) with a Likert scale of only 3 values (1,0, and −1) rather than the standard 5 values, called "anchor descriptors" [26]. Indeed, in the binary analysis, *increase*, *decrease*, and *neutral* act as anchor descriptors in a classical SCT [26,27]. For example, the student is expected to set the binary analysis between the diagnostic factor *Body temperature is 38 °C* and the diagnostic hypothesis *Pneumonia* as *I* (ie, increase). Any other input would be considered a mistake.

Importantly, one of the key differences between classical SCT and Hepius's binary analysis is that diagnostic factors and diagnostic hypotheses are not provided a priori but, instead, must be formulated by the students. This requires an active reflective process by the learner, which has an inherent educational value. A more detailed discussion of the differences between these 2 educational tools can be found in Multimedia Appendix 1 [23,26,28-32].

Pattern Analysis

In this section, a graph is automatically created to represent the binary analysis. The graph shows the diagnostic factor and diagnostic hypothesis nodes. An edge is created whenever the diagnostic factor and diagnostic hypothesis are increase-related or decrease-related according to the binary analysis. The graph is automatically converted into a cognitive fuzzy map [28,33] that displays an associated numerical weight for each node and edge. The student can modify the weight of diagnostic factor–diagnostic hypothesis edges according to their estimated importance of a specific diagnostic factor supporting the likelihood of a certain disease. The effect of such an action is visualized as a corresponding increase or decrease in the dimension of the diagnostic hypothesis node (Multimedia Appendix 1). This provides the student with immediate feedback.

Final Diagnosis

In this final step, the student must choose the final diagnosis among the list of diagnostic hypotheses; namely, the one characterized by the greatest probability of being correct.

Learning Analytics With Hepius

Learning analytics are used to improve and gain insights into learning processes by collecting, analyzing, and interpreting student-generated data [34]. Whenever a student performs an action with Hepius, the action is logged in the program database. As the simulation author (ie, the teacher) has explicitly specified what is the correct action, it is possible through analysis of the simulation execution logs to construct a detailed representation of the student's performance.

From this detailed representation, we computed synthetic metrics that provide *remedial insights* into the students' current capability to apply their competencies. By *remedial*, we mean that the insights may be used by the student, teacher, or other stakeholders to improve learning and teaching processes.

Test Descriptions

We conducted 2 clinical case simulations (tests) with Hepius to set our metrics. Test 1 (April 12, 2018) included 25 students participating in the Patient Management course (fifth year of the School of Medicine) at Humanitas University. The students

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performed a simulation on a virtual patient whose chief complaint was dyspnea, and the correct final diagnosis was pleural effusion secondary to Hodgkin lymphoma. Test 2 (May 21, 2018) included 36 students of the same course who performed a simulation on a patient who presented with abdominal pain, and the final diagnosis was acute cholecystitis.

All participants were familiar with the use of the program, were instructed to work independently, and had no time limit. In both tests, all actions performed were logged and subsequently analyzed.

Learning Metrics

Overall, the students' performance was split into seven sections, which included: (1) the identification of relevant information within the given clinical scenario, (2) history taking (ie, anamnesis), (3) performing a physical examination, (4) ordering medical tests, (5) formulating diagnostic hypotheses, (6) completing a binary analysis by matching the clinical data obtained throughout the simulation with the differential diagnosis, and (7) making the final diagnosis. For each section, we computed a sensitivity metric (ie, how much of the relevant information contained in each section the student was able to find) and a precision metric (ie, how many actions performed by the student were considered correct). These 2 components were combined with a harmonic mean (F_1), yielding a single score between 0 and 1 (1=perfect sensitivity and precision). This score was used as an index of the student's performance for each section (Table 1).

Table 1. Section metric description.

Section	Sensitivity metric	Precision metric	Section metric description
Input scenario	Percentage of DFs[a] identified out of all the DFs present in the input scenario	Percentage of DFs identified in the text out of all the text selections performed by the student	Performance in identifying DFs present in the input scenario without selecting nonrelevant text
Anamnesis	Percentage of relevant anamnestic questions identified out of all the relevant anamnestic questions present in the simulation	Percentage of relevant anamnestic questions out of all the questions asked by the student	Performance in asking all the relevant questions without asking superfluous questions
Physical examination	Percentage of relevant physical examinations performed out of all the relevant physical examinations present in the simulation	Percentage of relevant physical examinations performed out of all the physical examinations performed by the student	Performance in carrying out all the relevant physical examinations without carrying out superfluous physical examinations
Medical test	Percentage of relevant medical tests requested out of all the relevant medical tests present in the simulation	Percentage of relevant medical tests requested out of all the medical tests requested by the student	Performance in requesting all the relevant medical tests without asking for superfluous medical tests
DH[b]	Percentage of reasonable DHs identified out of all the reasonable DHs present in the simulation	Percentage of reasonable DHs identified out of all the DHs formulated by the student	Performance in identifying all the reasonable DHs without formulating inappropriate DHs
BA[c]	Percentage of BA mappings correctly executed on the first attempt out of the total number of BA mappings present in the simulation	Percentage of BA mappings correctly executed on the first attempt out of the total number of BA mappings executed by the student	Performance in identifying the correct DF–DH relationships (increase, neutral, and decrease) on the first attempt
Final diagnosis	Percentage of correct diagnoses identified by the student out of the total number of correct diagnoses present in the simulation	Percentage of correct diagnoses identified by the student out of the total number of diagnoses (correct and incorrect) formulated by the student	Performance in identifying the correct final diagnoses

[a]DF: diagnostic factor.

[b]DH: diagnostic hypothesis.

[c]BA: binary analysis.

By combining the 7 F_1 metric scores, we obtained a single number that was used as the student's overall score and compared it with the average class performance.

In addition, the 7 metrics were divided into two groups: one representing the capability to collect information (items 1, 2, 3, and 4) and the other representing the capability to analyze it (items 5, 6, and 7). The choice of developing an accuracy-based metric to assess performance in clinical data gathering rather than simply increasing a cumulative score whenever new information was obtained stemmed from the vast literature supporting the concept that good diagnosticians perform focused data gathering, primarily according to "illness scripts" [35-39]. In other words, this metric aims to measure quality rather than quantity of the collected clinical data.

In addition, for every simulation, the results were depicted on a radar chart. This provided a synthetic view of single student and mean class performance in each of the exercises. Individual radar charts can be superimposed and therefore compared with those achieved by the class.

In virtual patient simulations such as in real-life clinical cases, the proper sequence of diagnostic actions is often crucial for proper diagnosis [40]. In Hepius, these actions are defined as critical diagnostic acts and, when performed according to the expected execution order, they constitute the *desired execution*

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path. Thus, it is possible not only to analyze whether all crucial diagnostic acts were performed but also if their order was in keeping with the desired execution path. This is synthesized by an additional metric, the *methodological score*, which evaluates the overall diagnostic process [41-43].

To compute the methodological score, the sequence of crucial diagnostic acts performed by a student is converted into a string where each character represents a specific simulation section. The string is then simplified by removing the repetitions of contiguous identical characters. Hence, if the student first identifies 3 scenario factors, then asks 2 anamnestic questions, and, finally, executes 2 physical examinations, this would be initially converted into the string *sssaapp*. In such a string, *s* stands for scenario, *a* for anamnesis, and *p* for physical examination. This string would be further simplified into *sap*.

Let be the string associated with a specific simulation instance as described in the previous paragraph. We first compute the following 5 parameters: [p_1] is the Levenshtein similarity [44] between the string consisting of the first 3 characters of and the reference string *sap* as we have assumed that the expected path in collecting clinical data is going from the input scenario to the history taking and then to the physical examination [45,46]. [p_2] is the Levenshtein similarity between the string consisting of the last 2 characters of and the reference string *br*. *b* stands for binary analysis and *r* stands for result or final diagnosis selection. This is done because the expected last steps in a simulated case should be to analyze the collected clinical data to select the diagnostic hypothesis deemed to be correct according to the hypotheticodeductive model [47,48]. [p_3] is a parameter whose value is 1 if the first occurrence of *h* (hypothesis generation) precedes the first occurrence of *m* (medical test); otherwise, it is 0. Indeed, we assumed that medical tests should only be requested after at least one diagnostic hypothesis is formulated [49], also according to the *choosing wisely* campaign [50]. [p_4] is the percentage of sections present in out of the 7 possible sections. Hence, for instance, if Φ= *sapr*, then this parameter is 4/7. This is to ensure that the student makes a comprehensive assessment of the simulated patient without missing any sections of the case. [p_5] *is* the parameter $1/(1 + R)$, where R is the number of repetitions in . This is to favor a linear approach to the case over a repeated back-and-forth movement throughout the sections as it may occur with less proficient diagnosticians [35,36] possibly prone to premature closure [51,52].

These 5 parameters are then combined into a single score by computing the Euclidean norm of the vector whose dimensions are the 5 parameters:

$$\sqrt{(p_1^2 + p_2^2 + p_3^2 + p_4^2 + p_5^2)}.$$

Metric Validation

Our proposed metrics were preliminarily validated using test 1 results. As the simulated clinical case in test 1 was about Hodgkin lymphoma, to validate our new metrics, we compared the results with the current reference standard to assess students' knowledge in hematology at our university, that is, the hematology curricular examination. This examination consists of a multiple-choice question test on hematologic disease epidemiology, risk factors, clinical presentation, and diagnosis. The score ranges from 0 to 33.

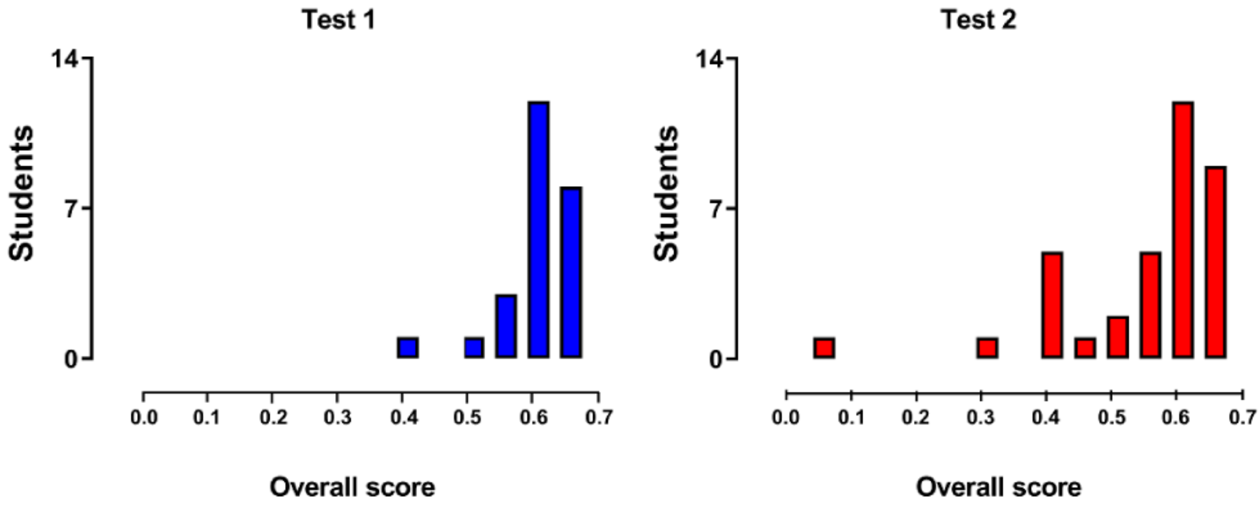
For validation, we compared the overall, collection, analytical, and methodological scores with the hematology examination score using the Spearman rank correlation test.

Results

Overview

The average class performance was slightly greater for test 1 (mean 0.59, SD 0.05) than for test 2 (mean 0.54, SD 0.12), with a larger score dispersion during test 2 as suggested by the greater SD. Figure 1 shows the class performance as assessed by the overall score distribution obtained during tests 1 and 2. The overall scores were not normally distributed, as evidenced by the left-skewed bars. This suggests that a minority of students performed worse than the class average, particularly during test 2.

Figure 1. Class overall performance scores during tests 1 and 2 as shown by histogram bar distribution. During test 2, the presence of bars on the left side points to the existence of students characterized by a weaker overall performance compared with the rest of the class. The range of each bar is 0.05.



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By grouping the 7 metrics into 2 knowledge domains (ie, data collection and data analysis; Figure 2), we could gain further insights into the students' expertise. Note the different dispersions of single scores during the 2 tests. The greater cluster of single scores during test 1 points to a more homogenous class performance. In addition, if only the overall performance scores were considered, students 202025 and 202041 (see arrows), for example, would appear to be at the same performance level. However, in their case, the identical overall scores (0.63) were reached in a different manner: student 202041 performed worse on the data collection exercise (collection rank 12 and analysis rank 5), whereas student 202025 performed poorly on the data analysis exercise (collection rank 3 and analysis rank 11).

Further analysis of student performance may be obtained using radar charts, as shown in Figure 3. In every diagram, the scores obtained in each of the 7 simulation sections can be summarized and compared with the performance of other students to detect the topics in which the student needs improvement.

Figure 2. Relationship between collection and analytical scores during test 1 (April 12) and test 2 (May 21). Each dot represents the performance of a single student. The ideal (maximal) performance score corresponds to 1.0. The dashed line indicates the median of the overall scores of the class. Note that students 202025 and 202041 (arrows) reached a similar overall score (0.63) in different ways. Student 202041 performed worse in the data collection exercise (collection rank 12 and analysis rank 5), whereas student 202025 performed poorly in the data analysis exercise (collection rank 3 and analysis rank 11) compared with the class results.

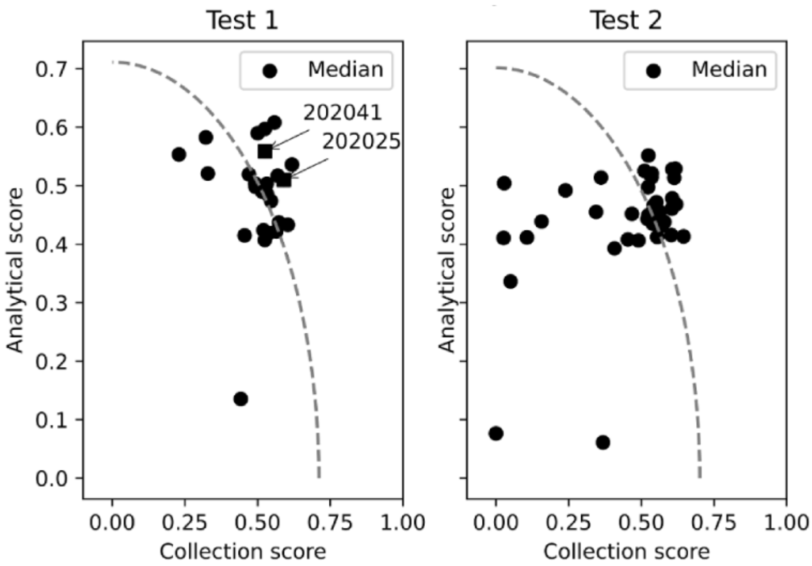
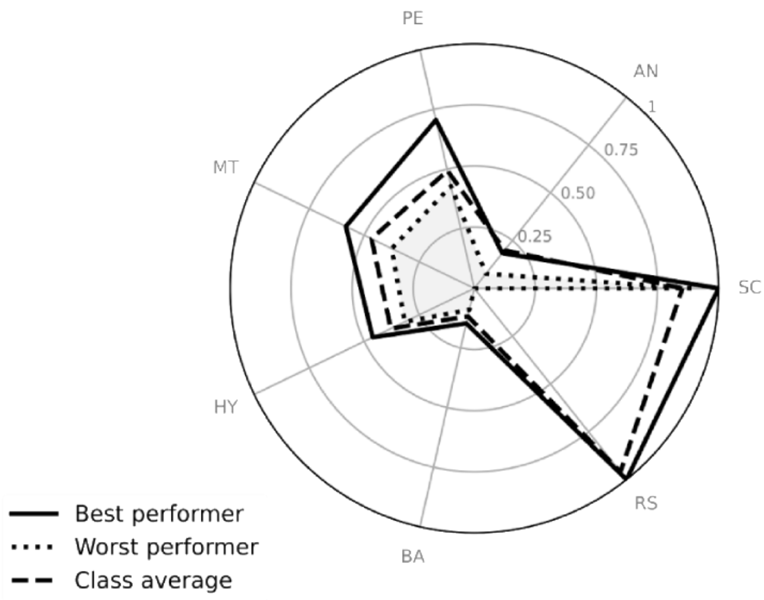


Figure 3. Radar graphs of the top- and bottom-performing students and average class results in each exercise section during test 1. Graphs enabled the comparison between the scores of the different exercise sections of the simulation as obtained by the top (continuous line) and bottom (long dashed line and grey area) performers and by the class (short dashed line). Note that the top-performing student scored consistently better than the average of the class on all tasks except the history-taking exercise. In contrast, the bottom performer scored less in every exercise except the anamnesis. The 2 students could be given individualized advice by teachers to overcome each specific weakness. The results refer to test 2. AN: anamnesis; BA: binary analysis; HY: hypothesis generation; MT: medical tests; PE: physical examination; RS: results; SC: scenario.



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Note that the top-performing student scored consistently better than the class average in all tasks except in the history-taking section. Conversely, the bottom performer reached the class average level only in the identification of relevant information within the given clinical scenario task (ie, interpretation of the input scenario).

Figure 4 provides insights on the students' skills in clinical methodology. The methodological score obtained by each student during tests 1 and 2 was plotted in relation to the overall score. The arrow indicates the student who scored poorly during test 2 as far as the clinical methodology was concerned despite an acceptable overall score.

Figure 5 displays the sequences of the crucial diagnostic acts that were performed by the students during the test 2 simulation and the number and percentage of users who performed each sequence. The 5 crucial diagnostic acts for test 2 were analysis of the input scenario (S), palpation of the abdomen (P), search for the Murphy sign (M), request for an abdominal ultrasound (U), and selection of the correct final diagnosis (D). Of the 36 students, only 3 (8%; SPUD) executed all 3 crucial diagnostic acts in the expected order, whereas 16 (44%) reached the correct final diagnosis without performing a physical examination.

Figure 4. Relationship between individual overall scores and corresponding methodological scores obtained during test 2. The arrow indicates the students who scored weakly as far as the clinical methodology is concerned, although the overall score was acceptable. Therefore, this student is specifically lacking in their way of addressing that diagnosis and needs ad hoc teacher's advice.

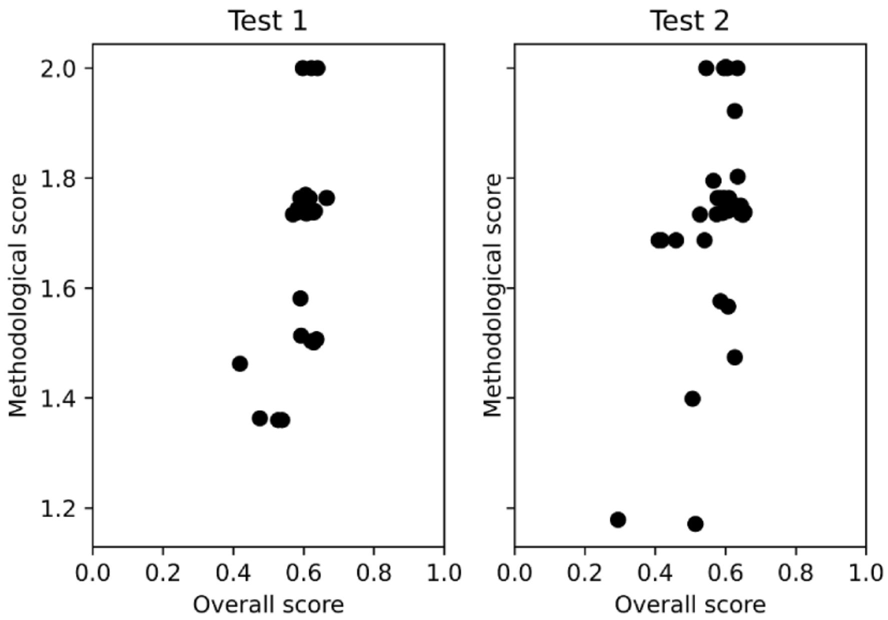
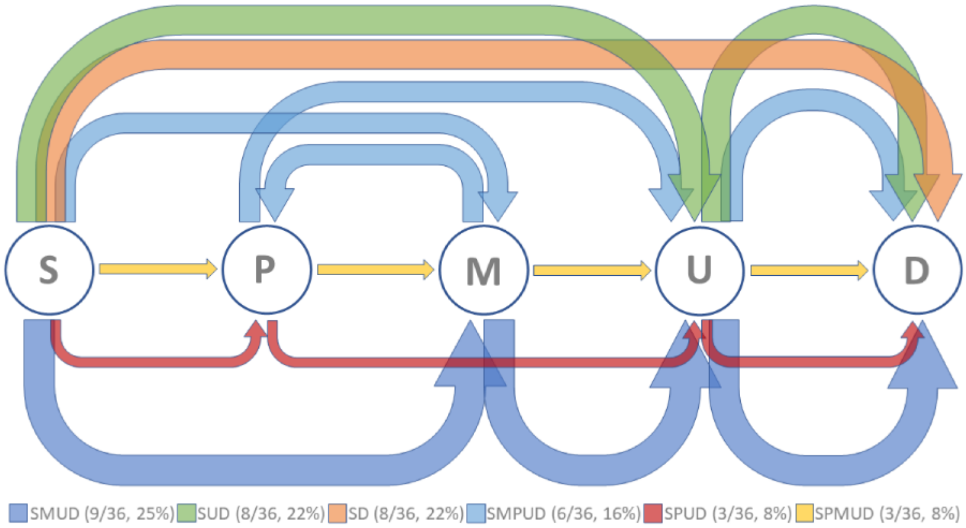


Figure 5. Critical diagnostic acts and expected execution path during test 2. The most likely diagnosis in that simulation was cholecystitis, and the key actions the user was expected to perform from the start (S) were previously set to be (1) palpation of the abdomen (right upper quadrant; P), (2) check for the Murphy sign (M), (3) request for abdomen ultrasonography (U), and (4) final diagnosis (D), corresponding to the PMUD pathway (thin yellow arrow). Each arrow represents a different execution flow. The width of the arrow is proportional to the number of students who followed that flow. Note that, of the 36 students, only 3 (8%) executed all 3 crucial diagnostic acts in the expected order, whereas 16 (44%) reached the correct final diagnosis without performing a physical exam, and 8 (22%) gave priority to abdomen sonography.



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Metric Validation

Of the 25 students who took test 1, 20 (80%) disclosed their hematology examination scores. Of those 20 students, 1 (5%) scored 25, 6 (30%) scored 29, and the remaining 13 (65%) scored 33. As reported in Table 2, there was no correlation between the hematology examination score and each of the Hepius metric scores.

Table 2. Results of the Spearman rank correlation test between the hematology examination score and the 4 main Hepius metrics.

Metric	Correlation index	*P* value
Overall score	0.2867	.22
Collection score	0.2786	.23
Analytical score	−0.0404	.87
Methodological score	0.0836	.73

Discussion

Principal Findings

In this paper, we describe the learning analytics obtained using the VPS Hepius [23] by analyzing the results of 2 tests performed by fifth-year students of the International Medical School at Humanitas University. In addition, learning analytics were preliminarily validated by comparing them with the hematology curricular examination score during test 1.

Learning analytics may provide teachers with valuable information on students' medical expertise and diagnostic reasoning skills. However, *remediable* should be the desired key feature of an education performance metric, in the specific sense of being suitable for remedial actions. Not all metrics have this characteristic, and most are designed only for evaluative purposes. For instance, the examination score is a global indicator of competence in a specific area and provides limited direct hints on what the student should focus on to improve competence. Evaluation, rather than remediation, is the primary goal of an ordinary examination score [53-56]. In contrast, the main metrics presented here (ie, overall score, collection score, analytical score, and methodological score) were developed primarily to provide educators with clues on student-centered *remedial actions*.

In this study, we first set basic statistical metrics to assess students' performance on single sections of the simulations. By combining these metrics, a convenient index (ie, the overall score) was computed featuring the students' global performance. In addition, relative graphs were drawn to synthesize the main results.

Much information is provided by such an analysis (Figure 1) and can be grouped as follows: (1) in-class information; for example, the left-sided bars in Figure 1—the test 2 histograms suggest that there are students who performed worse than most of the class; from an educational standpoint, this subgroup of students may be the target of specific teaching actions aimed at *sliding them to the right side of the graph*—and (2) cross-class information (eg, a comparison between the same classes of different academic years), which may provide teachers with information concerning their overall teaching performance over time.

Another valuable issue is the possibility of comparing student and class performances using the radar chart. This summarizes the single scores obtained during the different exercises of the simulation. Radar charts can be drawn for a single student or the entire class performance. In Figure 3, the top-performing student scored better than the rest of the class in all exercises but 1 (ie, history taking). This may reflect an overconfident behavior of the *smart* student who, having intuitively interpreted the clinical case using little information, did not deepen into the history taking, thus losing important information and falling into what is called an "early closure mistake" [57]. From a didactical point of view, each result obtained from simulations may provide specific insights on the overall class competence level and on specific features of each student's knowledge at the same time.

The overall score may provide information on the capability of the student to accurately analyze the clinical case. If appropriate strategies were used to avoid laziness and strict time bounds were preset, we might expect the overall score to be a proxy measure of the examination score as far as the related topics are concerned, although the results of this study do not support such a hypothesis.

However, the overall score would not be expected to be particularly useful as a remedial tool. Conversely, by making correlations between the 2 components of the overall score (ie, the data analysis and data collection scores), important operative information on students' diagnostic process could be obtained. For example, it is possible to assess the relative contribution of data analysis or data collection scores to the individual overall score, potentially giving the student specific advice to overcome any weakness. In addition, students who have an unsatisfactory analytical score should focus their attention on learning the specific UpToDate [58] documents automatically suggested by the Hepius Learner Model or enhancing their expertise in specific diseases through medical literature revision. In contrast, those with unsatisfactory data collection scores should exercise more with Hepius clinical cases or by directly interviewing real patients. Notably, such a hypothesis has not yet been validated and requires an ad hoc study.

The methodological score we propose aims to estimate the extent to which a student follows an adequate and realistic diagnostic process. We trust in clinical methodology and believe that its main principles must be learned by medical students [41-43] despite the recent widespread attitude in favor of using technologies for diagnostic purposes. A proper methodological approach to patients, both diagnostic and therapeutic and

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possibly evidence-based, may optimize diagnosis [59] and therapy [60] while diminishing the side effects [61,62]. Moreover, such a *choosing wisely* approach may eventually affect health care costs by remarkably reducing unnecessary tests, examinations, and treatments [63-66]. In a simulation of acute cholecystitis, by identifying the diagnostic actions performed and tracking the sequence of their execution, the use of Hepius revealed that, in the process of reaching the final diagnosis, >40% of the students (16/36, 44%) skipped the abdominal physical examination, and 22% (8/36) went straight to perform an abdominal ultrasound (Figure 4). There are 2 possible explanations for this finding. It might be because the students were dealing with a virtual simulation rather than a real patient on whom they would actually perform a complete abdominal physical examination. Alternatively, this finding may mirror students' overdependency on medical tests as a result of low confidence in their diagnostic self-capabilities. In both cases, an important educational challenge is posed requiring both recognition and properly targeted teaching action. An example of the latter would be a teacher referring a student with an insufficient methodological score to appropriate guidelines or flowcharts addressing the specific management of the disease or disorder.

In keeping with these considerations, we also sought to assess the magnitude of the methodological component within the individual student overall score by initially setting the 2 scores and then plotting the methodological score versus the overall score. As shown in Figure 4, some students performed quite poorly in clinical methodology [67] despite an acceptable overall score. In fact, their overall scores were close to the class average. Therefore, such an approach enabled us to identify students who could have taken learning advantages if promptly referred by the program or the teacher to an adequate UpToDate chapter or disease management guidelines.

Addressing cognitive processes using simulators is a daunting task that has been automatically approached in different ways. For example, Hege et al [68] used a VPS combined with a concept mapping tool to assess a number of actions performed by students, including problem identification, differential diagnosis setting, test requests, treatment options, and connections made. Similarly, Hepius can track the interactions between students and the simulator and synthesize them in a fuzzy cognitive map. Unlike the tool used by Hege et al [68], Hepius may identify the crucial diagnostic acts and their execution order without focusing on the diagnostic accuracy, defined as the capability to reach a correct final diagnosis on the first attempt [67]. We assumed a priori that, for every symptom, there was a set of fundamental actions that a student should take to reach a proper diagnosis. Importantly, the right order of actions was also essential as it may simplify the diagnostic pathway without the need for unnecessary tests [63,64]. Finally, we hypothesized that identifying these actions and their execution order within the simulation could be used as a proxy, possibly reflecting the students' overall cognitive process and methodological skills. Although all students (36/36, 100%) could reach a correct final diagnosis, our data suggest that only 8% (3/36) of them followed the desired sequence (the SPMUD path in Figure 5), which was assumed to be methodologically correct, whereas the rest adopted 5 different approaches. Through our simulator, we were able to identify students who omitted critical actions, indicating flaws in their methodological approach toward the patient that could potentially be amended through remediation actions such as learning specific management pathway guidelines.

When comparing overall, collection, analytical, and methodological scores with the students' hematology examination scores, we found no statistically significant correlation. However, this was expected as the scores addressed different skills [53]. The multiple-choice question examination evaluated global and in-depth competence regarding diseases. The VPS scores aimed to assess the students' ability to *collect* clinically relevant information (ie, collection score), *formulate a differential diagnosis* from scratch, *make proper connections* between the diagnostic hypothesis and collected clinical information (ie, analytical score), and solve the clinical case using a *proper clinical methodology* (ie, methodological score). Furthermore, it should be noted that the hematology examination scores were quite homogenous as 65% (13/20) of the students scored 33 out of 33 and 95% (19/20) scored >29. Although this may reflect a homogeneous education level of the class, it may also indicate a potential limitation of that evaluation method in properly grasping the wide variability of medical students' preparation [54-56].

Indeed, although multiple-choice question tests currently represent the mainstay of medical student evaluation, many have highlighted the weaknesses of such an evaluation tool [69,70].

Limitations

These results were obtained using 2 tests and a limited number of participants. This dampens the generalizability of the results on Hepius's effectiveness as a tool for the evaluation of medical students' diagnostic skills. In addition, our proposed learning analytics should undergo a more robust validation, possibly through psychometric methodology [29]; however, this would require a larger student population. The psychometric features characterizing the learning analytics proposed in this study are highlighted and discussed in Multimedia Appendix 1.

Conclusions

The use of Hepius by fifth-year medical students enabled us to obtain valuable educational information that was organized according to the proposed learning analytics. Insights obtained using learning analytics might better guide the teacher's feedback aimed at filling students' gaps in both medical knowledge and diagnostic methodology. It is important to highlight that Hepius learning analytics might also be used in different postgraduate settings, such as for the yearly assessment of residents' clinical training and general practitioner preparation within the continuing medical education context.

Ad hoc future studies are required to fully validate our proposed learning analytics.

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Acknowledgments

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Conflicts of Interest

None declared.

Multimedia Appendix 1
Hepius learner analytics psychometric features.
[DOCX File , 19 KB - mededu_v8i1e24372_app1.docx]

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Abbreviations

ITS: intelligent tutoring system
NLP: natural language processing
SCT: script concordance test
SNOMED–CT: Systematized Nomenclature of Medicine–Clinical Terms
VPS: virtual patient simulator

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Original Paper

e-Learning in Medical Education in Sri Lanka: Survey of Medical Undergraduates and New Graduates

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Abstract

Background: Medical education has undergone drastic changes with the advent of novel technologies that enable e-learning. Medical students are increasingly using e-learning methods, and universities have incorporated them into their curricula.

Objective: This study aimed at delineating the pattern of use of e-learning methods among medical undergraduates and new graduates of the Faculty of Medicine, University of Colombo, and identifying the challenges faced by these students in using e-learning methods.

Methods: A cross-sectional descriptive study was conducted in the Faculty of Medicine, University of Colombo, in April 2020, with the participation of current undergraduates and pre-intern medical graduates, using a self-administered questionnaire that collected data on sociodemographic details, pattern of use of learning methods, and challenges faced using e-learning methods.

Results: There were 778 respondents, with a response rate of 65.1% (778/1195). All the study participants used e-learning resources with varying frequencies, and all of them had at least 1 smart device with access to the internet. Electronic versions of standard textbooks (e-books), nonmedical websites, online lectures, medical websites, and medical phone apps were used by the majority. When comparing the extent of use of different learning methods, it appeared that students preferentially used traditional learning methods. The preference was influenced by the year of study and family income. The 3 most commonly used modalities for learning new study material and revising previously learned content were notes on paper material, textbooks (paper version), and e-books. The majority (98.7% [n=768]) of participants have encountered problems using e-learning resources. The most commonly faced problems were unavailability of free-of-charge access to some e-learning methods, expenses related to internet connection, poor connectivity of mobile internet, distractions while using online resources, and lack of storage space on electronic devices.

Conclusions: There is a high uptake of e-learning methods among Sri Lankan medical students. However, when comparing the extent of use of different learning methods, it appeared that students preferentially used traditional learning methods. A majority of the students have encountered problems when using e-learning methods, and most of these problems were related to poor economic status. Universities should take these factors into consideration when developing curricula in medical education.

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KEYWORDS

medical education; e-learning; Sri Lanka; medical students

Introduction

With the advent of novel technologies and portable smart devices, medical education has undergone a significant transformation worldwide [1]. In its broadest sense, electronic learning, or e-learning, is the use of internet in education [2]. Students are increasingly using e-learning methods to supplement traditional learning methods such as lectures, textbooks, print journals, and tutorials. There is a wide variety of e-learning methods available for medical education, such as online learning platforms, e-books (electronic versions of

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standard textbooks), e-journals, online question banks, medical websites, and mobile phone apps. Most educational institutions are incorporating these novel e-learning tools to deliver their curricula [3].

Sri Lanka is a middle-income country with a per capita gross domestic product of US $4102 [4]. Medical education is provided solely via state-sector universities in Sri Lanka. Nine state-sector universities provide undergraduate medical education, and approximately 1200 students graduate from these medical faculties each year. Sri Lankan universities predominantly use traditional teaching and learning methods to deliver medical education.

The Faculty of Medicine, University of Colombo, is the oldest and largest medical school in Sri Lanka, which produces approximately 200 medical graduates each year. A group of academics of the Faculty of Medicine, University of Colombo, established a virtual learning environment for medical undergraduates to supplement traditional learning methods over a decade ago [5].

Studies in other countries have demonstrated that e-learning methods are quite popular among medical students, and that these resources are used for learning new material as well as revising previously learned content [6]. Therefore, it is important to study the pattern of use of e-learning methods and challenges faced by Sri Lankan medical students in order to deliver medical education effectively.

This survey was conducted to identify (1) the pattern of use of e-learning methods among medical undergraduates and new graduates of the Faculty of Medicine, University of Colombo, and (2) the challenges faced by these students in using e-learning methods.

Methods

Overview

A cross-sectional descriptive study was conducted in the Faculty of Medicine, University of Colombo, in April 2020. This study was carried out with the participation of current undergraduates and pre-intern medical graduates who have completed their undergraduate degree in 2019 and are awaiting the commencement of internship.

Data were collected using a self-administered questionnaire consisting of 3 sections. The first section was on sociodemographic data.

The second section was designed to identify the pattern of use of learning methods. This section contained questions on the type of personal smart devices and internet facilities used, types of learning resources used, and the extent to which the students used different types of learning resources (both traditional and e-learning methods) for learning new material and for revising previously learned content. The extent of use of learning resources was assessed with a 5-point Likert scale (0=never, 1=rarely, 2=sometimes, 3=often, and 4=always).

The third section was on challenges faced in using e-learning methods. The participants were asked to select the challenges they faced from a list provided and were also given the opportunity to add anything that was not already on the list.

The questionnaire was developed on Google Forms. A separate Google Form was developed to obtain informed written consent and was emailed to all current undergraduates and pre-intern medical graduates. Those who consented were sent the link to fill and submit the questionnaire.

Data were collected anonymously onto a spreadsheet on Google Sheets and analyzed using SPSS, version 25 (IBM Corp). Descriptive statistics were outlined with frequencies, proportions, and percentages, and were summarized using mean with standard deviation. The significance of dichotomous variables was analyzed using chi-square test and those of continuous variables with one-way analysis of variance (ANOVA) test.

Ethics Approval

Ethics approval for the study was obtained from the Ethics Review Committee of the National Hospital of Sri Lanka (approval number: ERC/NHSL/2020/012).

Availability of Data and Materials

Data sets supporting the conclusions of this article are included within the article. Additional data at individual student level cannot be provided as per confidentiality agreement.

Results

There were 778 respondents, with a response rate of 65.1% (778/1195). Of the 778 participants, 450 (57.8%) were female. The highest percentage of the participants (230/778, 29.6%) were from Colombo district, where the commercial capital of the country is located. Approximately one third (263/778, 33.8%) of the participants had a monthly family income less than 50,000 LKR (US $250). A vast majority (710/778, 91.2%) did not have an income of their own and hence were dependent on their parents' income. The demographic characteristics of the sample are summarized in Table 1.

A vast majority (748/778, 96.1%) of the study participants owned a smartphone. All those who did not own a smartphone owned some other portable smart-device with internet connectivity such as a tablet/iPad or a laptop. Ninety-one percent of the study participants owned at least one other portable smart device in addition to a smartphone. These data are illustrated in Figure 1.

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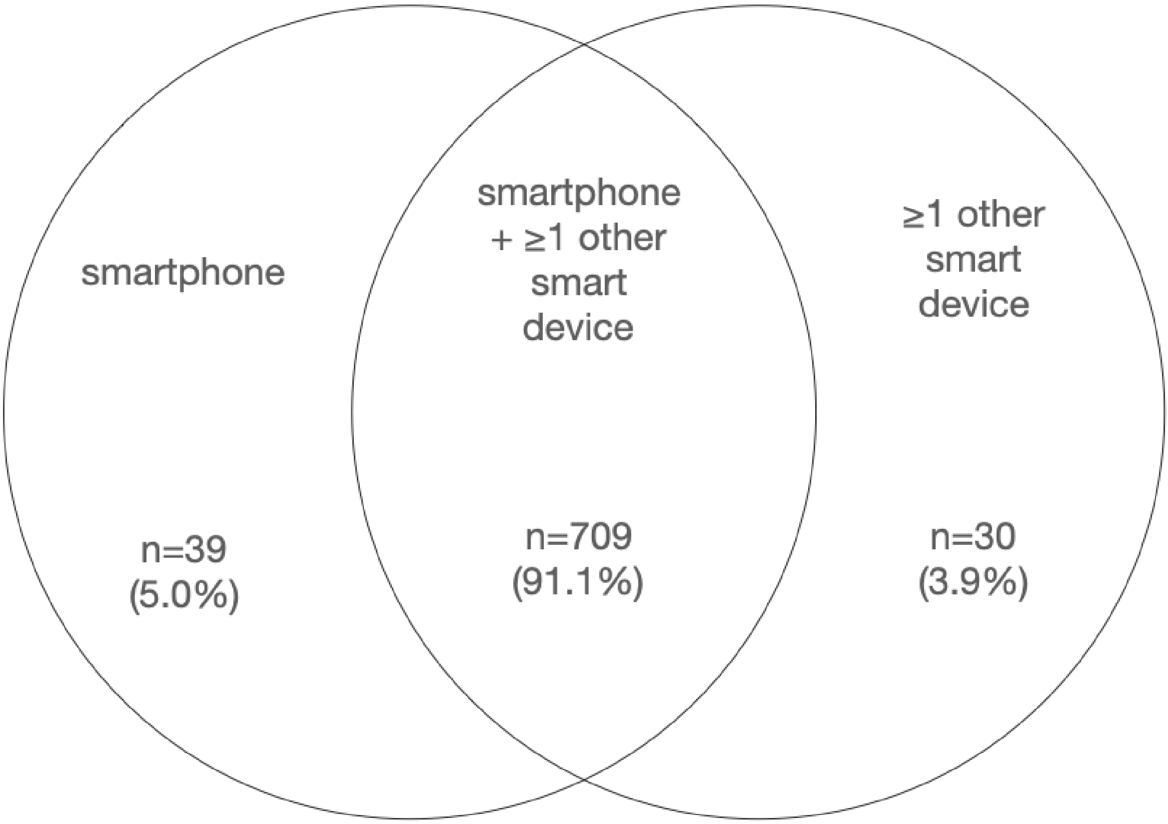
Table 1. Demographic characteristics of the sample.

Characteristics	Values
Gender, n (%)	
Male	328 (42.2)
Female	450 (57.8)
Age (years), mean (SD; range)	23.37 (2.19; 19-28)
District of residence, n (%)	
Within Colombo	230 (29.6)
Outside Colombo	548 (70.4)
Family income[a], n (%)	
<50,000	263 (33.8)
50,001-100,000	245 (31.5)
100,001-150,000	87 (11.2)
>150,000	168 (21.6)
Not answered	15 (1.9)
Having own income, n (%)	
Yes	62 (8.0)
No	710 (91.2)
Not answered	6 (0.8)

[a]Family income is in LKR; 200 LKR is approximately US $1.

Figure 1. Ownership of smartphones and other smart devices.



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All participants had access to the internet. A majority (394/778, 50.6%) connected to the internet using both Wi-Fi and cellular data. The rest used either Wi-Fi only (45/778, 5.8%) or cellular data only (339/778, 43.6%).

All of the study participants used e-learning methods. Electronic versions of standard textbooks (e-books), nonmedical websites (eg, Wikipedia), online lectures, medical websites, and medical phone apps were used by the majority of study participants. The percentage of participants using different types of e-learning resources are summarized in Table 2.

A majority (483/778, 62.1%) used e-learning methods for learning new material as well as for revising previously learned content, whereas 205 (26.3%) used it only for learning new material, and 90 (11.6%) used it only for revising previously learned content.

The extent of use of different methods (both traditional and e-learning) for learning new material and for revising previously learned content are illustrated in Figure 2 and Figure 3, respectively.

Table 2. Percentage of participants using e-learning modalities (n=778).

e-Learning modality	Participants, n (%)
e-Books (electronic versions of standard textbooks)	704 (90.5)
Nonmedical websites (eg, Wikipedia)	528 (67.9)
Online lectures	525 (67.5)
Medical websites	515 (66.2)
Medical phone apps	399 (51.3)
Self-made notes on electronic devices	302 (38.8)
e-Journals	223 (28.7)
Interactive online learning platforms	158 (20.3)
Online question banks	129 (16.6)

Figure 2. Extent of use of learning methods for learning new material.

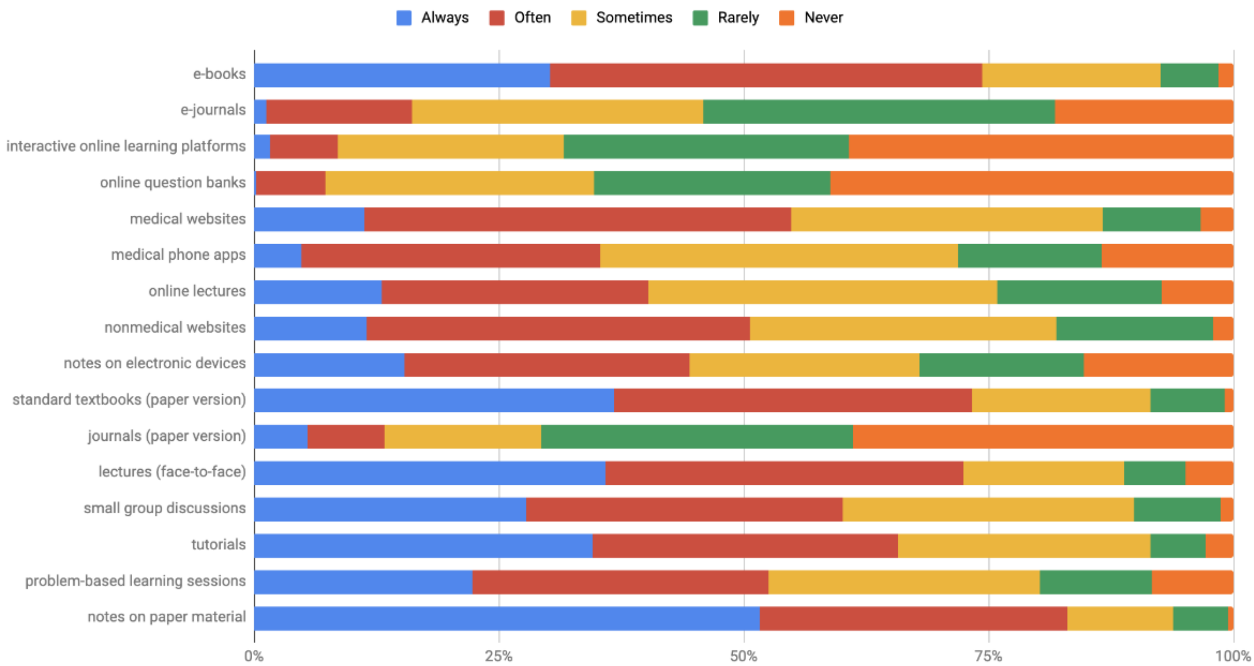

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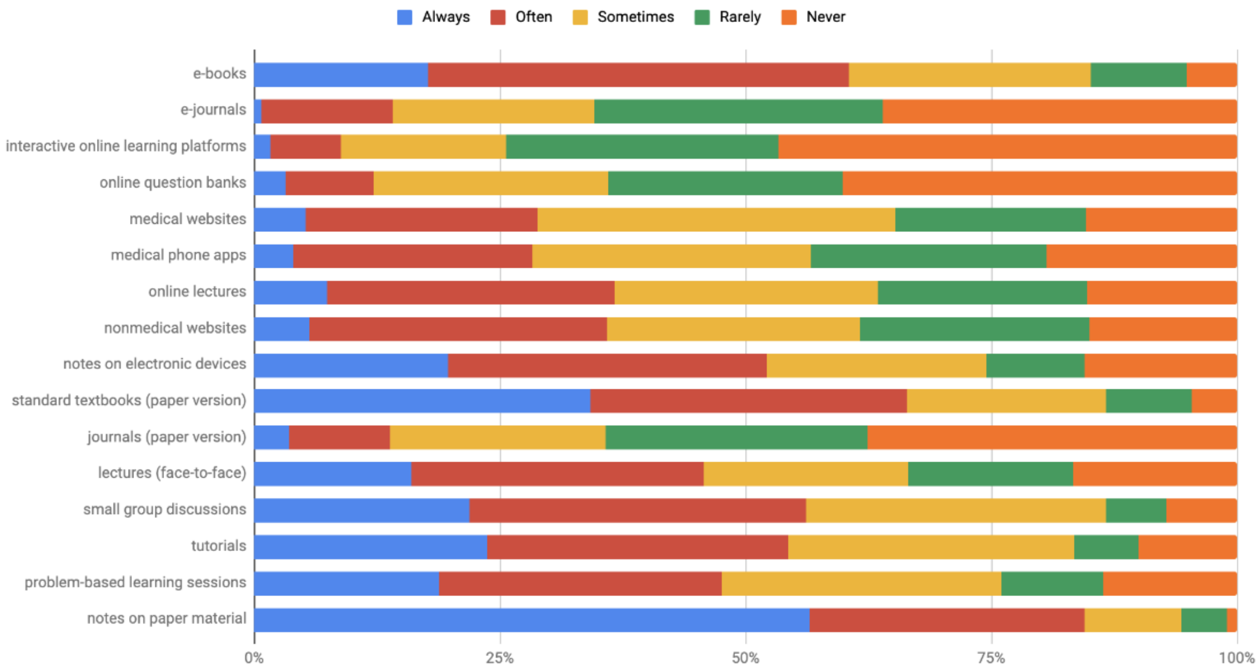
Figure 3. Extent of use of learning methods for revising previously learned content.



The 3 most commonly used modalities for learning new material were notes on paper material, e-books, and textbooks (paper version). The 3 least used modalities were online question banks, interactive online learning platforms, and journals (paper version).

The 3 most commonly used modalities for revising previously learned content were notes on paper material, textbooks (paper version), and e-books. The 3 least used modalities were interactive online learning platforms, online question banks, and e-journals.

A score was assigned for the use of each type of resource according to the extent of use, which is as follows: "Never=0," "Rarely=1," "Sometimes=2," "Often=3," and "Always=4." Each participant's score for using e-learning methods (e-learning score) was calculated by adding the scores for e-books, e-journals, interactive online learning platforms, online question banks, medical websites, medical phone apps, online lectures, nonmedical websites, and self-made notes on electronic devices, and dividing by the number of items. The score for using traditional learning methods (traditional methods score) was calculated in a similar manner by adding the scores for standard textbooks, journals, face-to-face lectures, small group discussions, tutorials, problem-based learning sessions, and notes on paper material, and dividing by the number of items.

The mean "e-learning score" was 1.74 (SD 0.695), and the mean "traditional methods score" was 2.38 (SD 0.759), with a statistically significant difference between the two (P<.001).

Chi-square test was used for determining factors associated with the preferred type of learning methods (Table 3).

The preferred type of learning methods was influenced by the year of study and family income (P<.001).

One-way ANOVA test was used to determine factors influencing "e-learning score" and "traditional methods score" (Table 4).

The extent of using e-learning methods was influenced by the year of study (P<.001), gender (P=.003), family income (P=.01), and having one's own income (P<.001), whereas the extent of using traditional learning methods was influenced by gender (P<.001), district of residence (P=.01), and having an own income (P=.003).

The problems encountered by students in using e-learning methods and the percentage of participants experiencing each of these problems are summarized in Table 5.

The vast majority (768/778, 98.7%) of the participants have encountered at least 1 problem when using e-learning resources. The challenges faced by the majority include unavailability of free-of-charge access to some e-learning methods (eg, journals), expenses related to internet connection, poor connectivity of mobile internet, distractions while using online resources (eg, notifications from other apps), and lack of storage space on electronic devices.

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Table 3. Analysis of factors associated with the preferred type of learning methods.

Variable	e-Learning methods preferred, n (%)	Traditional learning methods preferred, n (%)	Chi-square (*P* value)
Year of study			55.59 (<.001)
1st year	34 (4.37)	114 (14.65)	
2nd year	10 (1.29)	120 (15.42)	
3rd year	20 (2.57)	164 (21.07)	
4th year	15 (1.93)	105 (13.49)	
5th year	55 (7.07)	95 (12.21)	
Pre-intern	10 (1.29)	30 (3.86)	
Gender			1.69 (.19)
Male	67 (8.61)	255 (32.78)	
Female	77 (9.89)	373 (47.94)	
District of residence			5.13 (.02)
Within Colombo	31 (3.98)	195 (25.06)	
Outside Colombo	113 (14.52)	433 (55.66)	
Family income[a]			22.27 (<.001)
<50,000	39 (5.01)	224 (28.79)	
50,001-100,000	39 (5.01)	206 (26.48)	
100,001-150,000	16 (2.06)	71 (9.13)	
>150,000	26 (3.34)	53 (6.81)	
Not answered	7 (0.89)	8 (1.03)	
Having own income			2.02 (.36)
Yes	14 (1.79)	48 (6.17)	
No	130 (16.71)	574 (73.78)	
Not answered	0	6 (0.77)	

[a]Family income is in LKR; 200 LKR is approximately US $1.

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Table 4. Factors influencing the extent of using e-learning and traditional learning methods.

Variable	e-Learning score, mean (SD)	*P* value	Traditional methods score, mean (SD)	*P* value
Year of study		<.001		.02
1st year	1.89 (0.71)		2.42 (0.86)	
2nd year	1.47 (0.76)		2.39 (0.59)	
3rd year	1.55 (0.72)		2.23 (0.81)	
4th year	1.73 (0.59)		2.47 (0.64)	
5th year	1.96 (0.56)		2.41 (0.80)	
Pre-intern	2.19 (0.42)		2.62 (0.66)	
Gender		.003		<.001
Male	1.66 (0.77)		2.19 (0.76)	
Female	1.81 (0.63)		2.53 (0.73)	
District of residence		.95		.01
Within Colombo	1.75 (0.75)		2.49 (0.70)	
Outside Colombo	1.74 (0.67)		2.34 (0.78)	
Family income[a]		.01		.04
<50,000	1.67 (0.67)		2.38 (0.82)	
50,001-100,000	1.81 (0.66)		2.49 (0.71)	
100,001-150,000	1.57 (0.77)		2.30 (0.66)	
>150,000	1.85 (0.70)		2.29 (0.77)	
Not answered	1.73 (0.89)		2.19 (0.67)	
Having own income		<.001		.003
Yes	2.22 (0.49)		2.70 (0.75)	
No	1.71 (0.69)		2.36 (0.76)	
Not answered	1.37 (0.20)		2.45 (0.29)	

[a]Family income is in LKR; 200 LKR is approximately US $1.

Table 5. Problems encountered using e-learning methods (n=778).

Problem encountered using e-learning methods	Participants experiencing the problem, n (%)
Unavailability of free-of-charge access to some e-learning methods (eg, journals)	460 (59.1)
Expenses related to internet connection	435 (55.9)
Poor connectivity of mobile internet	426 (54.8)
Distractions while using online resources (eg, notifications from other apps)	409 (52.5)
Lack of storage space on electronic devices	401 (51.5)
Lack of awareness of available free e-learning resources	302 (38.8)
Difficulty in identifying authentic learning material on the internet	285 (36.6)
Poor availability of internet connection	196 (25.2)
Lack of time to use e-learning methods	137 (17.6)
Unwillingness to use technology	102 (13.1)
Poor availability of electronic devices	83 (10.7)
Eye strain	80 (10.3)
Language barrier	75 (9.6)
No problems encountered	10 (1.3)

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Discussion

Principal Findings

This is the first study in Sri Lanka to identify the pattern of using e-learning resources by medical students and the challenges faced by these students in using e-learning methods.

It showed that all of the study participants used e-learning resources with varying frequencies for learning new content and revising previously learned content, and that all of them had at least 1 smart device with access to the internet.

The most commonly used e-learning modalities were electronic versions of standard textbooks (e-books), nonmedical websites (eg, Wikipedia), online lectures, medical websites, and medical phone apps.

When a score was assigned for use of each type of resource according to the extent of use, the "traditional methods score" was significantly higher than the "e-learning score," indicating that students preferentially used traditional learning methods. The preferred type of learning methods was influenced by the year of study and family income. A higher proportion of participants in lower-income categories preferred traditional learning methods over e-learning methods. This might be due to the costs associated with mobile devices and internet connectivity.

The extent of using e-learning methods was influenced by the year of study, gender, family income, and having one's own income. The extent of using traditional learning methods was influenced by gender, district of residence, and having one's own income. It is interesting to note that some of these factors overlap. Female participants and those with their own income use both e-learning methods and traditional methods more than their respective counterparts.

Most of the challenges encountered in using e-learning resources stem from poor economic status.

Sri Lankan data on the topic of e-learning in medical education are limited. A study carried out on second-year medical students (n=138) of the Faculty of Medicine, University of Colombo, to assess computer literacy and attitudes toward e-learning in 2012 had shown that 93.5% of students owned a computer, and 95% of them had an internet connection [7]. However, the majority of students (65.7%) spent less time on their computer for learning purposes. When comparing these findings with that of this study, it is evident that there is an increase in the available resources as well as using e-learning in medical education in Sri Lanka over the past 8 years.

It is also important to look at studies on e-learning in medical education from other countries for comparison.

A 2017 study carried out on first-year medical students (n=284) of University of Nigeria Teaching Hospital, Enugu State, Nigeria, to assess their readiness for e-learning had shown that 76.1% had access to laptops [8]. It had also shown that these students were ready to move beyond the traditional face-to-face approach, believing that e-learning will improve the quality of their learning.

A 2014 study performed on students (n=270) of Shiraz University of Medical Sciences, Iran, had shown that although the majority (78.5%) of students owned personal computers, only 21.3% used them regularly for learning [9]. Poor connectivity had been the main limiting factor for internet use.

When compared to other middle-income countries, Sri Lankan medical students appear to have better facilities and a better uptake of e-learning resources despite the challenges they face.

In a 2009 study conducted among second-year medical students (n=269) at the School of Medicine and Dentistry at Queen's University Belfast, Ireland, to assess the place for e-learning in clinical skills, the majority (89.2%) of the respondents had their own computer, and 99.6% of them had internet connectivity [10].

A study carried out on penultimate and final year medical students (n=350) of University of Sydney and University of New South Wales, Australia, had shown that, in 2019, despite a general trend toward using e-learning methods, traditional methods such as attending face-to-face lectures remain popular for learning new material [6]. This indicates that, even in more affluent countries, traditional teaching and learning methods still play a major role in medical education.

Medical faculties in Sri Lanka can take the findings of this study into account when developing curricula for their students. Effective e-learning modalities should be used to supplement traditional teaching and learning methods. When using e-learning methods, measures should be taken to minimize difficulties encountered by students. For example, e-learning resources could be developed in such a way that even students with weak internet connections are able to access them. Institutional access for paid online learning resources could be provided to students. A stipend to cover expenses related to internet connectivity and loan facilities to purchase mobile devices and data storage devices could be provided for students with economic difficulties. Moreover, libraries could purchase electronic versions of standard textbooks and provide free access to students.

There are some limitations in this study. This study was conducted in 1 medical faculty, and it might not be possible to generalize the findings to other medical schools in the country. However, similar trends have been observed in studies conducted in other countries, indicating that the trends may not vary greatly in other institutions.

The questionnaire was sent to students via email as a Google Form, which requires a smart device with internet connectivity for access. Therefore, it is possible that those who responded are more likely to use e-learning methods than those who did not.

Further qualitative studies are recommended to gain a deeper understanding and to find measures to overcome challenges faced by medical students in using e-learning methods in Sri Lanka. It is also important to study the factors influencing delivery of medical education via e-learning methods and the challenges faced by educators in preparing e-teaching material.

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Conclusions

This cross-sectional survey from the largest medical faculty of Sri Lanka showed that there is a high uptake of e-learning methods among Sri Lankan medical students. However, when comparing the extent of use of different types of learning methods, it was evident that students preferentially used traditional learning methods. A majority of the students encountered problems when using e-learning methods, and most of these problems were related to poor economic status. Universities should take these factors into consideration when developing curricula in medical education.

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Authors' Contributions

The author confirms sole responsibility for study conception and design, data collection, analysis, interpretation of results, and manuscript preparation.

Conflicts of Interest

None declared.

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Abbreviations

ANOVA: analysis of variance

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Viewpoint

Preparing Medical Students for the Final Examinations During the COVID-19 Crisis: A Bumpy Ride to the Finishing Line

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Abstract

In this viewpoint, we share and reflect on the experiences of final-year students preparing for a high-stakes examination at the Faculty of Medicine, Universiti Kebangsaan Malaysia during the COVID-19 pandemic. We highlight the new challenges faced during web-based remote learning and major differences in the clinical learning environment at our teaching hospital, which was one of the designated COVID-19 centers in Malaysia. We also document how a face-to-face professional examination was conducted for final-year medical students at our institution despite in times of a global health crisis. The lessons learned throughout this process address the importance of resilience and adaptability in unprecedented times. Further, we recommend appropriate measures that could be applied by medical schools across the world to improve the delivery of quality medical education during a crisis in the years to come.

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KEYWORDS

COVID-19; undergraduate medical education; medical students; clinical competency; pandemic

Introduction

The COVID-19 pandemic has had a profound impact on medical education, particularly in terms of how teaching and assessments are delivered. The immediate effect of the implementation of a nationwide Restriction of Movement Order by the Malaysian government has impacted all students in local medical schools to discontinue educational activities in clinical environments. Our university teaching hospital was declared as COVID-19 designated center in Malaysia to help ease the burden of the national health care system. Clinic sessions, elective medical procedures, and surgeries were all postponed. This resulted in a major shift in the patient pool available at the wards. There were more inpatients with medical or surgical emergencies. Patients suspected of any respiratory infection were admitted to the severe acute respiratory infections wards, limiting the respiratory specialty ward to patients with lung malignancy and chronic respiratory illnesses. The wards were a controlled zone with heightened safety protocols, and staff had to abide by very strict standard operational procedures to prevent the transmission of the virus.

Health care professionals who were involved in undergraduate teaching activities were actively working in the frontlines, providing crucial services to patients with COVID-19 and the community. As a result, it is necessary that medical students have relevant skills and knowledge to respond appropriately if the need arises. The development of pandemic preparedness modules to provide undergraduate students with essential skills has been documented in several studies [1,2]. Another crucial factor to consider is the continuity of medical studies. It is critical to maintain learning continuity as well as a steady supply of doctors and experts for the health care system.

There is a paucity of research on the steps taken by medical schools to ensure academic continuity during a pandemic. Issues such as medical school closure, maintaining safety and hygiene, and leveraging technology for e-learning are frequently prioritized. A recent article published by Sungkyunkwan

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University School of Medicine discussed a pandemic preparedness module during the Middle East respiratory syndrome outbreak, which involved the formation of a special committee, rescheduling of academic calendar, and conducting clinical clerkships at other institutions. However, the authors pointed out that their module was not holistic enough to cover all areas [3]. The Yong Loo Lin School of Medicine, National University of Singapore documented the use of e-learning tools such as Entrada, which included uploading webcast links and lecture slides, creating web-based quizzes, and setting up and conducting web-based meetings. The authors also highlighted on the modifications made to clinical examination during the COVID-19 pandemic, such as strict safety and hygiene protocols and the use of simulated patients in clinical examination stations [4]. On the other hand, the Duke-National University Singapore Medical School applied the following key principles in organizing final year examinations for medical students, such as strict infection control, cohorting of all participant groups, social distancing of individuals, Zoom-facilitated briefings, and Wi-fi–enabled data-gathering from iPad-based objective structured clinical examination (OSCE) scoring system [5].

In this paper, we highlight the new challenges faced during web-based remote learning and major differences in the clinical learning environment at our teaching hospital, which was one of the COVID-19 designated centers in Malaysia. The lessons learned throughout this process address the importance of resilience and adaptability in unprecedented times.

Challenges in Medical Education During the Pandemic and its Solutions

During the COVID-19 pandemic, students had to quickly acclimatize to learning totally from home. All classes were transitioned to the internet, with lectures and seminars delivered over virtual platforms such as Zoom and Microsoft Teams. There was a strong sense of appreciation toward clinicians who were on COVID-19 duty, yet still finding the time to teach students. Although the complete switch to web-based learning eased the burden on the faculty and teaching physicians, medical students were facing some challenges while attempting to adapt to the entire process. Among the major challenges faced by students were issues with Wi-Fi connectivity, such as poor internet coverage, low internet speed, and local network congestion. A study has shown that 40% of Universiti Kebangsaan Malaysia (UKM) medical students have a poor internet connection (<5 Mbps) [6]. Some students did not have access to Wi-Fi at their homes owing to low socioeconomic backgrounds. Mobile data packages were just not affordable for these students simply because each web-based lesson would consume a large amount of data. These technical glitches resulted in frequent absenteeism from web-based classes. To overcome this problem, the UKM collaborated with a local corporation to provide free access to SIM cards with mobile data to all students. This was a beneficial program that helped reduce the burden of students, especially for those who depended on mobile data to go through the web-based learning process and also to keep them connected with their lecturers.

Another challenge of e-learning is how to practice clinical skills efficiently [7]. Students were slowly losing touch with their clinical skills while learning from home as there was no exposure to real-life patient encounters throughout the lockdown period. History-taking, physical examinations, and performing simple ward procedures are daily routines for final-year medical students in the clinical setting. Efficient teaching of practical and clinical skills could be overcome by using virtual reality simulators [8]. Being at home, away from the campus environment, the motivation to study was fading away. For educators, the main challenge is to stimulate and sustain the learner's motivation. One approach to meet this challenge was provided by the Attention, Relevance, Confidence, and Satisfaction (ARCS) model of motivation, which analyzes the motivational characteristics of a group of learners and designs motivational strategies on the basis of this analysis. The ARCS model is based on four motivational concepts: Attention, Relevance, Confidence, and Satisfaction [9]. To overcome the lack of motivation among students, the faculty provided students with access to multiple virtual patient learning environments such as the DxR Clinician software and Medscape Patient Simulations. It is an interactive platform where students could play an active role in managing virtual simulated patients, without the fear of being judged or doubt regarding making a mistake that could be a threat to patient safety, while receiving constructive feedback from the lecturers via the university's learning management system. This indirectly encouraged students toward learning more rigorously and improving their clinical reasoning skills.

Being at home with no access to patients and their medical records, students were running out of material to present during the virtual case-based discussions. Therefore, these virtual learning platforms came in handy by supplying a pool of problem-based learning case studies created from real patient data. These platforms were a win-win situation for both students and the lecturers. Students were engaged in active, self-directed learning with a variety of patient presentations in the comfort of their homes. In addition, lecturers were able to identify the strengths and weaknesses in student's clinical reasoning skills and closely monitor their progress via quantifiable assessments and scoring tools in these platforms. All forms of student activities and academic events were conducted virtually, including study groups. One cannot afford to study alone as a final-year medical student because there is a lot to learn in such a short duration. Study groups have encouraged series of discussions and peer teachings to improve knowledge retention. It also acts as a support system for medical students to share their bittersweet experiences in the clinical setting. Owing to the pandemic, study groups had to transition to the internet as well. Case scenarios and mock examination practice questions were discussed via videoconferencing. It is undeniable that nothing could replace the significance of learning from a patient with regard to learning medicine. The real-life patient encounters and lessons we learn from them are aspects that would make the most impact in medical education. However, in a crisis such as the COVID-19 pandemic, flexibility and adaptation are essential to keep the ball rolling.

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As months passed by, the COVID-19 situation in Malaysia was only taking a turn for the worse, which then led to multiple extensions to the nationwide lockdown period. Final-year medical students were experiencing anxiety with regard to whether they will have their clinical examinations and graduate on time because of the uncertainties surrounding the COVID-19 pandemic and the hassle of applying for residency training thereafter. Final-year medical students in other parts of the world were being fast-tracked in the final part of their undergraduate journey to increase the frontline workforce on the battle against the COVID-19 pandemic. However, there was a national level policy decision made by the Malaysian Medical Council that medical students in their final year must undertake their exit examination to qualify as a doctor. This examination will test the cognitive and clinical skills of the final year medical students. Hence, medical students were concerned, and doubts were raised about how and when the final examination would take place. Additionally, students were stressed on thinking about how their mental health would fare, given the prospect of months of web-based content and revision, alongside concerns regarding their preparedness for life as a qualified doctor.

After the faculty administration scrutinized all the available options, the decision was to extend the final examination to 1 month after the initially planned date with a similar format to that of the previous years. However, some adaptations were made. First, the timeline was changed. In previous years, UKM medical students were provided a 2-week study leave to prepare for both theory and clinical examinations, and these examinations were conjoined one after the other, without any large remedial period in between. This time around, students were provided a 3-week-long study leave to prepare for the theory assessment. Following that, the faculty provided a 2-month remedial period to better facilitate students to practice clinical skills. Owing to the nationwide lockdown, all medical students have lost a discernible 4 months of clinical exposure. Therefore, students were not entirely sure if the preparations were sufficient for the clinical assessments, which involved interaction with real patients and in conducting medical procedures. However, the remedial period was useful to an extent. Nevertheless, students still faced difficulties in spending time interacting with patients owing to limited access to the wards and patients. Only 6 medical students were allowed to be in the ward at a particular time, and ward rounds were not made compulsory for students to attend. Students were segregated into smaller groups, and rosters were put up at the entrance to every ward. Each small group was allowed to spend limited time in the ward, depending on the respective departments. Year 3 and year 4 medical students also had their clinical rotations concurrently with the final-year students. With so many medical students around and such limited time in the ward, one can only do so much to gain hands-on experience. Being students and the most junior in the medical hierarchy, students are not always fortunate to encounter opportunities to perform procedures while on clinical duty. Students also faced countless rejections from patients as there were simply too many medical students approaching a particular patient on the same day, especially patients with long hospital stays.

The traditional phrase of “see one, do one, teach one” is no longer relevant in this age where medical negligence and litigations are on the rise. Furthermore, a single chance will never be sufficient to attain competence in a particular procedure. This is where simulation provides a great edge. Certain medical schools in Kuala Lumpur, Malaysia, are implementing an open learning concept. The UKM medical faculty has its Basic Simulation Lab (BSL) and Clinical Skills Lab (CSL), where medical students are allowed access at their convenience, to practice procedures while watching related self-instructional videos (SIVs) provided on site [10]. The BSL and CSL were established in collaboration with the Department of Medical Education to facilitate teaching and training in small groups and self-directed learning through modules and videos made available for users. The BSL and CSL are replicas of the actual clinical environment, which provides students with common medical and surgical procedures in accordance with the medical curriculum. It is very suitable as a learning space, especially learning that involves history-taking and physical examination of patients by simulation. Through simulation and mannequins, the learner would have repeated chances to perform specific skills, especially the rare and uncommon ones. Simulations thereby overcome learning merely by chance, which is often insufficient and dangerous in developing the competence of medical personnel [11]. The SIVs are used as a guide for self-practice, and the procedures were recorded and sent to the lecturers for personalized coaching. This method of learning freed up a considerable amount of time for the lecturers and allowed students to practice at their own pace.

Mental health issues were also on the rise during the pandemic. The global prevalence of anxiety and depression among medical students is 33.8% and 33% respectively, both substantially higher than those in the general population [12,13]. Having to take the biggest examination in medical school and also battle through the challenges that come with a global pandemic is mentally taxing. Positive correlations between academic delays and anxiety symptoms have been reported by studies on Chinese college students during the COVID-19 pandemic [14]. Furthermore, every time students approached a new patient, there was always doubt and fear regarding the patient’s COVID-19 status, although they were fully in personal protective equipment. There were no vaccines available in the country yet at that time, and with clinical examinations around the corner, succumbing to COVID-19 and creating a cluster among medical students was the last thing one would expect. Moreover, there was suspicion among students if they will be competent enough to become safe doctors. All these issues were flocking in the form of negative thoughts, which placed students in a constant state of paranoia.

Planning and Delivery of the Final Examinations

Conducting a high-stakes examination during a pandemic is a challenging and arduous process. Several medical schools have documented their experience of planning and conducting high-stakes examinations during the COVID-19 pandemic [4,5,15]. Multiple sets of web-based facilitated briefings on the

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flow process and standard operating procedures were conducted before the examinations. Students were required to fill a health declaration form issued by the Ministry of Higher Education to ensure that they were symptom-free, had not been in close contact with patients with COVID-19, and had not travelled overseas for the last 14 days prior to the examination. Strict infection control and personal hygiene measures were taken before entering the examination hall, such as temperature screening, social distancing. and ensuring that every student was wearing a face mask and sanitized their hands. The process and format of the examination were rather similar to those conducted in previous years, except that there was more gap in between tables to ensure proper distancing among candidates.

After a 2-month remedial period, the clinical examinations were conducted. The clinical examinations at the UKM medical school are divided into two components: the long case presentation in the morning followed by the OSCEs in the evening. Most medical students find the clinical examination challenging and nerve-wracking as one cannot predict the case scenarios that would be involved. The examination took place in a special examination ward located in the main building of the teaching hospital. Students were divided into smaller cohorts, and each cohort was managed in a separate circuit with different reporting and holding rooms. Examiners and candidates did not cross over to other circuits. All were required to wear face masks with face shields or goggles and don white plastic aprons, and always maintain social distance throughout the examination. There were no changes made to the format, station design, and content of the examination. As there was some difficulty in recruiting real patients, some stations were replaced with simulated patients. In the long case examination, candidates who were provided case scenarios with simulated patients were only required to take a complete history from the patient and physical examinations were omitted. Hence, the scoring rubric was adjusted accordingly in those stations. The examination coordinators and administration staff eased the transit from station to station by providing students directions. It was a fairly well-organized examination despite the hassle of strict infection control and cleaning in between circuits. Some examiners had access to Wi-Fi–enabled data-gathering for the examination scoring system; however, most of them had to jot down the marks manually on the scoring sheet. To date, there have been no reports of COVID-19 infections among the candidates, examiners, and examination coordinators. The passing rate was similar to that in previous years. Students who failed the final examinations would undergo supplementary clinical rotations for 6 months and have another opportunity to demonstrate their readiness for clinical practice.

Recommendations and Take-home Messages

The recent COVID-19 pandemic has interrupted the training of medical students worldwide. The lessons learned throughout this process address the importance of resilience and adaptability in all aspects of medical education. Unprecedented times such as this one test the preparedness of the faculty to cater to the learning needs of medical students. Therefore, these are some recommendations that may help improve the quality of medical education among medical students during a pandemic.

Accessibility to an Internet Connection

The main hindrance to web-based learning during the pandemic was accessibility to an internet connection. As large data are exchanged during web-based classes, a stable, high-speed network is paramount in the campus environment. In lockdown circumstances, where students are learning from home, the university should collaborate with major telecommunication companies to provide students with subsidized mobile data and broadband packages to facilitate remote learning.

Experimenting With Different Teaching Styles and Learning Methods

Traditional slide-based lectures via virtual platforms could induce boredom, especially when they last long durations. Educators could include games and interactive sections in their lectures to improve student engagement; for example, Kahoot quizzes. Lectures and educational videos could be prerecorded or recorded during the class so that students who have internet connectivity problems during the scheduled class would not fall behind their lessons. In the context of teaching clinical skills, lecturers could invite patients with stable health conditions to join web-based teaching sessions. History-taking and clinical counseling skills, for example, could be carried out with a real patient via videoconferencing instead of student-to-student role plays. In cases where the real patient could not be present, virtual ward rounds could be organized for clinical students. Faculty should also provide students with free access to e-books and scientific journals for convenient referencing. Furthermore, Massive Open Online Courses such as the World Health Organization's OpenWHO platform should be promoted to students to supplement their learning experience.

Modifications to Methods of Evaluation and Assessments

There is a need for a fair system of evaluating the academic performances of medical students. During a high-stake examination such as the final-year examinations, all potential barriers faced by medical students should be considered when evaluations are performed. When there is a strict movement control order and state or district borders are closed, selected patients for OSCEs and external examiners would face difficulties in being present on the scheduled examination dates. In special cases of this sort, students could be assessed remotely via videoconferencing for convenience purposes. OSCE stations that require students to be in very close proximity with the patient, such as conducting a fundoscopic examination, should be conducted using appropriate mannequins. Weightage and carry marks should be adjusted accordingly. Long case presentation stations that involve simulated patients and do not require students to perform physical examinations should have a modified marking scheme. In these scenarios, more weightage should be given to the case presentation and quality of discussion in the viva voce session. The final professional examinations are so unique that one only gets to experience it once in their entire medical school life. When circumstances allow, mock examinations should be conducted to familiarize

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students with the flow process of the examination and also provide them the first-hand feeling of taking part in a high-stakes examination.

Conclusions

To summarize, we discussed in detail the contingency preparations by the Faculty of Medicine of the UKM, which covered a wide range of aspects such as the curriculum, examination process, as well as safety precautions for all students and staff during the COVID-19 pandemic. In the COVID-19 era, conducting a final-year medical examination poses significant challenges. Hence, medical schools should allow some flexibility when conducting these examinations. We believe that our recommendations will be helpful to other medical schools as they assess their preparedness for a pandemic.

Conflicts of Interest

None declared.

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Abbreviations

ARCS: Attention, Relevance, Confidence, and Satisfaction
BSL: Basic Simulation Lab
CSL: Clinical Skills Lab
OSCE: objective structured clinical examination

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SIV: self-instructional video
UKM: Universiti Kebangsaan Malaysia

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Original Paper

Student-Run Online Journal Club Initiative During a Time of Crisis: Survey Study

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Abstract

Background: Since the closure of university campuses due to COVID-19 in spring 2020 necessitated a quick transition to online courses, medical students were isolated from hospitals and universities, negatively impacting their education. During this time, medical students had no opportunity to participate in academic discussions and were also socially isolated. Furthermore, medical doctors and professors of medical schools were given additional responsibilities during the pandemic because they were the frontliners in the fight against COVID-19. As a result, they did not have enough time to contribute effectively to medical student education.

Objective: This paper describes the establishment of the Cerrahpasa Neuroscience Society Journal Clubs, a group of entirely student-run online journal clubs at Cerrahpasa Faculty of Medicine, Istanbul University-Cerrahpasa.

Methods: The website, mass emailing, and social media accounts were used to announce the online journal clubs. Only medical students were eligible to apply. Journal clubs included psychiatry, neuroradiology, neurosurgery, neurology, and neuroscience. Following the last journal club meeting, a questionnaire created by the society's board was distributed to the participants. SPSS Statistics (version 26) was used for statistical analysis.

Results: Since March 15, 2021, synchronous online journal club meetings have been held every 2 weeks on a weekday using Google Meet, Microsoft Teams, or Zoom. Meetings of each journal club lasted approximately 1 hour on average. Interstudent interaction across multiple institutions was achieved since a total of 45 students from 11 different universities attended the meetings on a regular basis. Students on the society's board served as academic mentors for the clubs. The clubs received excellent feedback from participants, with an overall contentment score of 4.32 out of 5.

Conclusions: By establishing these clubs, we have created a venue for academic discussions, which helps to reduce the negative impact of the pandemic on education. In addition, we believe it greatly aided students in staying in touch with their peers, thereby reducing the sense of isolation. We realize that traditional journal clubs are run by faculty; however, we believe that this experience demonstrated that medical students could run a journal club on their own since the feedback from participants was excellent. Additionally, as a medical student, being a journal club academic mentor is a challenging responsibility; however, having this responsibility significantly improved our academic mentors' leadership abilities.

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KEYWORDS

online journal club; medical student; distance learning; COVID-19; undergraduate education; student journal club; online education; establishment; initiative; literature; research; publishing; education

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Introduction

SARS-CoV-2, which is responsible for COVID-19, was declared a pandemic by the World Health Organization on March 11, 2020, posing new challenges for all medical students and faculty, as well as requiring remote learning by universities worldwide [1]. Platforms such as Zoom, Google Meet, and Microsoft Teams became the "new normal," and the primary venue of teaching and socializing, in only a few weeks. This also influenced how journal clubs are run.

Since their introduction by Sir William Osler in 1875, journal clubs have a long history in the medical sciences [2]. Traditionally, they involved regular gatherings with a group of doctors and/or students to discuss publications. The original purpose was to help physicians stay up to date with current research and implement the research findings to clinical practice [3,4]. The concept of journal clubs evolved and widened as the depth of the literature continued to increase. As evidence-based learning has become more integrated in medical education, journal clubs have become a venue for not only keeping physicians up to date but also for dissecting and assessing the quality of study methodology [5].

Most journal clubs were still held in person prior to COVID-19. One significant problem of in-person journal clubs is that participants find it difficult to attend meetings on a regular basis, perhaps due to logistic challenges. This problem can be solved by using online platforms that allow participants to join the meeting from any location, thereby providing a flexible and feasible platform for evidence-based learning [6]. These meetings (ie, online journal clubs) can be held synchronously via platforms such as Google Meet or Microsoft Teams, or asynchronously via internet forums such as Twitter. Asynchronous virtual journal clubs can take place regardless of time or place; participants can contribute at a specified time period without waiting for the other participants to be online, which usually occurs on an internet blog. Online journal clubs, whether synchronous or asynchronous, enable national and international collaboration by bridging geographical boundaries [7]. They may also involve experts and even the authors of the discussed articles. In this way, online journal clubs create a venue that motivates medical professionals, increases networking, and minimizes social isolation, especially during the COVID-19 pandemic. It is worth noting that although the COVID-19 pandemic resulted in a rapid shift to online learning, online journal clubs have existed for a long time [8].

According to Keet et al [7], journal clubs are especially effective in resident training and continuing medical education. In addition, journal clubs can be very beneficial to medical students, especially when they are quarantined and forced to stay away from clinical environments during the pandemic. During this time of crisis, we believe that an online journal club could help medical students stay motivated, socialize, boost their medical knowledge, and teach them academic medicine. Since professors, lecturers, and other medical doctors were assigned additional responsibilities during the pandemic to aid in the battle against COVID-19, they were unavailable to run a journal club. Consequently, as the Cerrahpasa Neuroscience Society board, we have decided to establish and run a group of student-led synchronous online journal clubs. The aim of this article is to discuss the organization and outcomes of our online journal club experience based on survey results.

Methods

Ethics Considerations

This study was conducted in compliance with the principles of the Declaration of Helsinki. Ethical approval was waived because the Cerrahpasa Neuroscience Society's journal clubs are run independently of the university. Informed consent was obtained from all participants.

Clubs and Application

Cerrahpasa Neuroscience Society is a student-led organization that was founded in 2018 at Cerrahpasa Faculty of Medicine, Istanbul University-Cerrahpasa (IUC). In our society, we established five distinct online journal clubs with regard to the subfields of neuroscience: psychiatry, neuroradiology, neurosurgery, neurology, and neuroscience journal clubs. On February 19, 2021, all of the online journal clubs were announced to all Cerrahpasa Neuroscience Society email newsletter subscribers, as well as via postings on the Cerrahpasa Neuroscience Society's Facebook, Twitter, and Instagram accounts. Between February 22 and 28, 2021, applications were accepted online at the society's website for each journal club. Only pregraduate medical students were eligible to apply. Although the presentation language was announced to be Turkish, all of the reviewed papers were published in English. Therefore, applicants were reminded that English proficiency would be necessary for efficacious meetings. The number of participants in each journal club was intended to be between 9 and 12. The absolute number of participants was decided after the applications were submitted. Students on the society's board served as academic mentors for the clubs. The board members of the society include Atacan Zeybek, Batuhan Davuş, Elif Kaymaz, Ferit Ulaş Özkan, Kardelen İnan, Naz Bilaloğlu, Öykü Melek Tepe, Zeynep Sude Furkan, Zeynep Özcan, Burak Berksu Özkara, Mert Karabacak, and Duygu Demet Alpaydın. The board members were selected via voting by the members of the Cerrahpasa Neuroscience Society based on their performance and contribution to the club in the 2019-2020 education year.

Mission

Careful planning and the establishment of clear, defined goals are essential for a successful journal club [7]. Therefore, before the sessions began, the following goals were declared to the participants: to create an ideal discussion environment, to improve critical appraisal skills, to learn to review the literature, to learn to select appropriate articles, and to improve presentation skills. In an attempt to reach our goals, the society's board also provided mentors with educational materials on how to run a journal club.

Articles

Initially, each academic mentor selected articles for their participants to present based on their interests in a particular topic relevant to the journal club they run. All selected articles

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were in English, published in a well-respected journal, and possibly appealing to the students. However, after providing educational material on how to perform a literature review, a few academic mentors chose to provide presenters with autonomy by allowing them to choose what to present, which is an idea to motivate participants based on self-determination theory (SDT). SDT explains motivational processes and inspired us to foster this element of learning [9]. Furthermore, academic mentors presented one article in their first meetings to serve as an example and to share key components of an ideal presentation.

Questionnaire and Analysis: Evaluation of Cerrahpasa Neuroscience Society Journal Clubs

Two authors (MK and DA) created a questionnaire that was controlled and evaluated by the first author (BO) on July 3, 2021. The questionnaire was sent via email to participants who attended more than 80% of the meetings, with a response deadline of July 9, 2021. To receive their certificate of participation, participants were required to complete the questionnaire, which resulted in a 100% response rate. The questionnaire was divided into three sections. The first section asked participants about their universities, current grades, journal clubs they attended, and the platform they used during meetings. The second section included 22 items that questioned participants' level of contentment with our journal club. The third section included 8 items pertaining to the preferences of the participants (Table 1). Questions in sections 2 and 3 were assessed on a 5-point Likert scale, with 1 representing "completely disagree" and 5 representing "completely agree." Negatively worded questions were reverse-scored (1=5, 2=4, etc).

SPSS Statistics (version 26) was used for statistical analysis. Because the first section of the questionnaire was about the demographics and the third section considered the preferences of the attendees, all statistics were calculated based on the second section of the questionnaire. The internal consistency of the questionnaire's second section was assessed using Cronbach α. Independent-sample *t* tests were used to investigate group differences. Pearson correlations were used to investigate bivariate relationships between items of the questionnaire. *P* values less than .05 were regarded as statistically significant.

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Table 1. Questionnaire items for evaluation of Cerrahpasa Neuroscience Society journal clubs.

Question number	Question
Contentment questions	
Q1	Objectives of the journal club (provision of ideal discussion medium, development of critical-thinking skills, choice of up-to-date articles, efficient presentation) were explained clearly prior to meetings.
Q2	Objectives of the journal club were achieved.
Q3	Peer education in journal club meetings was more favorable in comparison to classical medical education.
Q4	I would like to see journal clubs in other medical schools.
Q5	Interval between meetings was sufficient for preparing presentations.
Q6	Interval between meetings was sufficient for reading three papers.
Q7	Articles chosen were compatible to the specified subfield of the journal club.
Q8	Articles chosen were up to date.
Q9	Competence of academic mentors and their conduct of meetings were sufficient.
Q10	Meetings were understandable for me.
Q11	Attendance to the journal club helped me improve my critical-thinking skills.
Q12	My understanding and evaluation of methodology in research studies improved.
Q13	Now, it is easier for me to determine the weaknesses and strengths of articles.
Q14	My enthusiasm for future journal clubs or presentation activities increased.
Q15	My presentation skills improved.
Q16	My desire to be involved in research projects increased.
Q17	My ability to understand and evaluate medical articles increased.
Q18	I found it helpful to be able to interact with students from other medical schools.
Q19	I would be more anxious if the meetings were in person.
Q20	Online meeting platforms that were used for meetings were easy to use.
QR1[a]	Meetings were not productive because of technical issues (internet speed, internet connectivity).
QR2[a]	It was hard to get used to meetings being online.
Preference questions	
P1	I wish there were journal clubs for subfields other than neurology, neurosurgery, neuroradiology, psychiatry, and neuroradiology.
P2	I would prefer shorter meetings.
P3	I would prefer longer meetings
P4	I would prefer meetings with more people.
P5	I would prefer meetings with less people.
P6	Journal clubs are more beneficial for clinical students rather than preclinical students.
P7	I would prefer online journal club meetings when the medical education becomes in person again.
P8	I would prefer meetings were chaired by faculty members.

[a]Questions that were reverse-scored.

Results

Participants

A total of 13 applicants were accepted for neurology, 8 for neuroradiology, 8 for neuroscience, 9 for neurosurgery, and 12 for psychiatry, and they attended the meetings on a regular basis. Five participants, out of a total of 45, participated in two clubs. For each journal club, a member of our society's general assembly was assigned as the academic mentor.

Execution

Synchronous online journal club meetings were held every 2 weeks on a weekday since March 15, 2021, using Google Meet, Microsoft Teams, or Zoom. Each journal club's meetings were approximately 1 hour long on average. First, an educational meeting was held to demonstrate how to present an article to participants. Following the first educational meeting, three articles were presented by three participants, who were selected 2 weeks earlier by academic mentors, at each of the subsequent meetings. In addition to presenters, each participant was

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expected to read the selected three articles in 2 weeks. A 10-minute presentation aided by slideshows was followed by a 10-minute discussion for each article. Academic mentors did not present any articles, but instead guided the discussions following each presentation. In some journal clubs, after the 1-hour meeting, participants and academic mentors would stay on the online platform to chat about their personal lives, which we believe contributed significantly to the motivation of participants and success of our journal club. The last meeting took place on June 29, 2021.

Results of the Questionnaire

All Participants

Cronbach α was used to evaluate the internal consistency of the second section of the questionnaire in terms of reliability, which reached .84 (target value>.70).

The journal club general contentment score was calculated by averaging all answers given by each participant to the second section of the questionnaire (Figure 1). The mean contentment score was 4.32, indicating that the journal club participants were very satisfied. The mean value for each item ranged from 3.07 to 4.67 (Figure 2).

Among the 45 participants, 27 (60%) were IUC students, whereas 18 (40%) were students from other universities, including Hacettepe University, Balikesir University, Hitit University, Kutahya Health Sciences University, Altinbas University, Istanbul University, Ankara University, Ataturk University, Gazi University, and Kahramanmaras Sutçu Imam University. In terms of the journal club general contentment score, there was no difference (*P*=.86) between IUC students (mean 4.32) and participants from other universities (mean 4.31).

Pearson correlations were performed to examine bivariate associations between the variables. Three items (reversed question one [QR1], reversed question 2 [QR2], and question 19 [Q19]) yielded a low Pearson correlation, indicating that these three items were scored significantly lower than other items by participants.

The first item with a low Pearson correlation was "Meetings were not productive because of technical issues (internet speed, internet connectivity)" with a mean score of 4 among the items with low Pearson correlation (reversed). This finding indicates that most participants were satisfied with their online connection; however, some participants encountered technical difficulties. The second item, with a mean score of 4.02 (reversed), was "It was hard to get used to meetings being online," indicating that a few participants struggled to adapt to the online nature of the club. The last item was "I would be more anxious if the meetings were in person" with a mean score of 3.07. This finding implies that participants are unsure whether they would be more nervous in a face-to-face meeting as opposed to an online meeting.

Figure 1. Responses to the preference-related questions (P1-P8; see Table 1 for complete descriptions of each item) on a 5-point Likert scale (1=completely disagree, 5=completely agree).

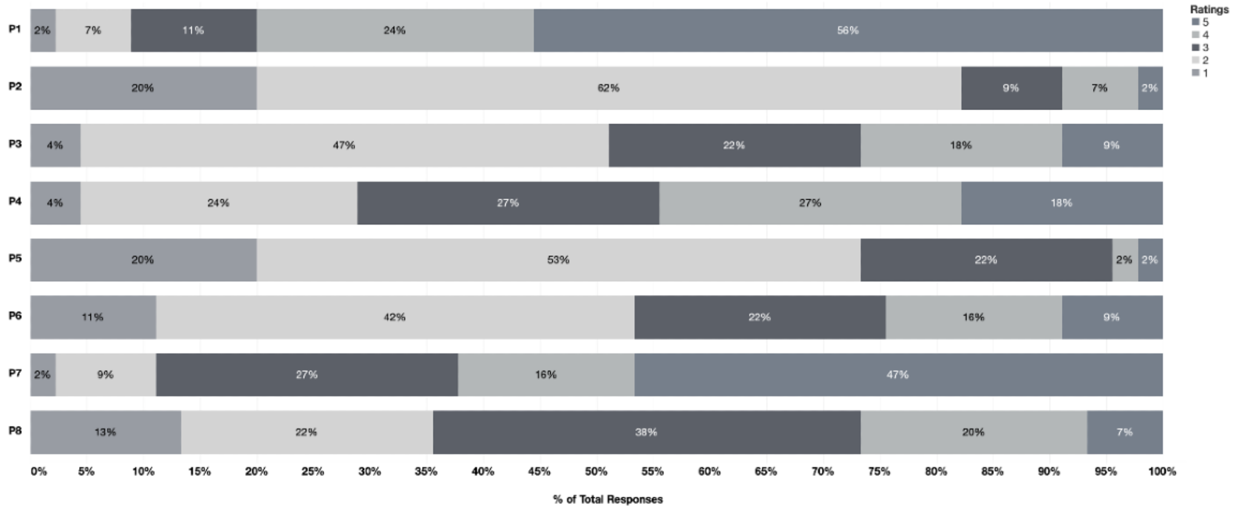

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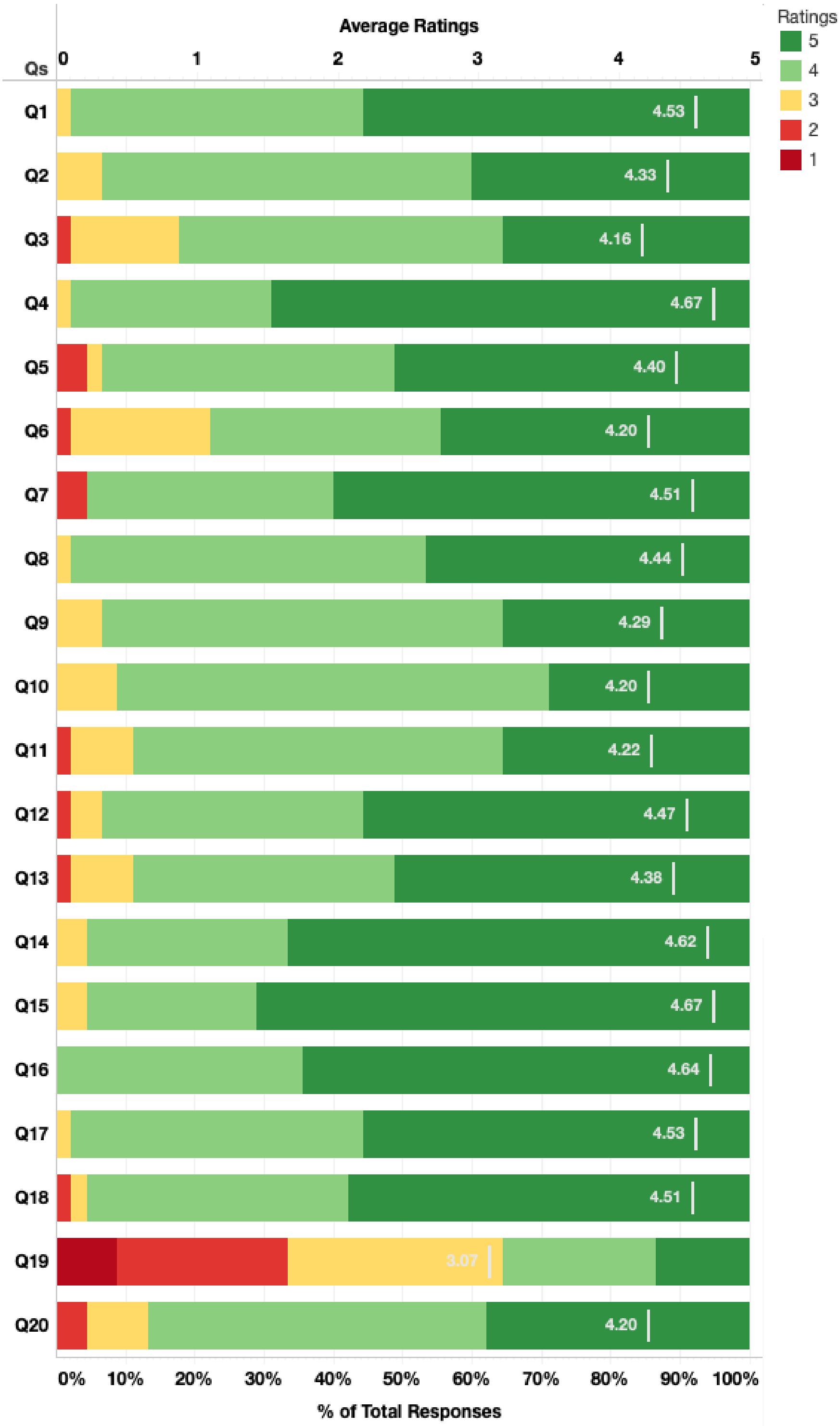
Figure 2. Average ratings for each question (see Table 1 for descriptions of each item) on a scale of 1 (strongly disagree) to 5 (strongly agree).



Preclinical and Clinical Medical Students

In Turkey, medical education consists of 3 years of basic medical sciences courses (for preclinical medical students), 2 years of clerkships, and 1 year of internship (for clinical medical students). Participants included 38 preclinical medical students with 6 in their first year, 12 in their second year, and 20 in their third year. By contrast, there were only 7 clinical students, including 6 in their fourth year and 1 in their fifth year.

The independent-sample *t* test was used to compare the responses of these two groups, including responses to the preference questions. Significant differences between the answers of these two groups were found for the scores on only two items: preference 5 (P5) and preference 6 (P6). The first item that significantly differed between preclinical (mean 2) and clinical (mean 2.86) medical students (P=.01) was "I would prefer meetings with less people." Despite the fact that neither preclinical nor clinical students prefer meetings in smaller

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groups, this finding suggests that clinical medical students are more likely to prefer small-group journal clubs. The second significantly different item between preclinical and clinical medical students was "Journal clubs are more beneficial for clinical students rather than preclinical students" (mean 2.50 and 3.71, respectively; P=.008). This finding suggests that clinical medical students think that participation in a journal club would be better after completing preclinical studies. However, we are very pleased with the positive attitude of preclinical participants, which indicates that they think the journal club has greatly benefited them even though they are still in the early stages of their medical education. As a result, we believe that preclinical medical students should be encouraged to participate in journal clubs.

The independent-samples t test was also used to compare the answers of IUC students and non-IUC students. There was no statistically significant difference in responses between IUC and non-IUC students (P values ranged from .08 to .94 for each item).

Discussion

Principal Results

This innovation widened students' exposure to journal clubs, as many participants did not have this available at their university. Participation in our journal clubs is a valuable experience for our students, since involvement in a journal club was shown to enhance academic reading habits [10]. Participants' responses indicated satisfaction with the way student academic mentors handled their responsibilities. The independent-samples t test revealed that the overall experience for IUC and non-IUC students was the same, indicating that institutions should be more welcoming of students from other institutions. Overall contentment scores suggested that peer-to-peer journal clubs could be satisfactory to participants and should be encouraged when the senior doctors or professors are unavailable to supervise.

Strengths and Limitations

The COVID-19 pandemic has disrupted education, which, when combined with physical distance, has resulted in challenges in disseminating valid education for medical students, as well as social isolation. We present a student-led online synchronous journal club format that promotes education of medical students while also fostering peer interaction. During a time of societal stress, our journal club is unique in that it is entirely student-run, with participants consisting entirely of medical students, and it brings together a large number of medical students from all over Turkey, creating a venue for medical students, who are one of the most affected groups by self-quarantine [11].

Our survey provided valuable information on the essence of an online synchronous journal club for medical students. To obtain these valuable data, filling out the survey was required to obtain an online journal club certificate, which resulted in a 100% response rate. Some authors in the literature mentioned low response rates, which we believe could be resolved by making survey responses mandatory to receive a certificate [3,5,12].

Interstudent interaction across multiple institutions was generally accomplished through face-to-face conferences and courses, which were all completely cancelled during the pandemic. Our journal club had 45 participants from 11 universities, demonstrating that online events can partially compensate for the lack of in-person events for interinstitutional peer interaction. We believe that interinstitutional peer interaction is important not only for medical education but also for motivation and psychological well-being during this time of crisis. Furthermore, because we were aware that an online journal club was not available at other Turkey-based universities, we accepted non-IUC students to support these students, who did not have the same opportunity as IUC students. The mean score for the item "I would like to see journal clubs in other medical schools" among non-IUC participants was 4.56, indicating that such organizations are needed in other universities that participants attend. The multi-institutional nature of our journal clubs demonstrates that our online journal clubs were truly nationwide, with students from all over Turkey participating.

We believe that the small number of participants significantly contributed to the success of our journal club, because it is more difficult for participants to focus in large groups and for us to see how many participants are actively listening [3]. Furthermore, to achieve better results during meetings, participants in our journal club would turn on their webcams even if they were not presenting an article, making them more active and focused, especially during the discussion component of the meeting.

Since our journal club was entirely run by students, academic mentors in each journal club were members of the society's board. Even though running a journal club was a huge responsibility for a pregraduate medical student, we believe that our mentors did a great job since overall participant contentment was very high. Another finding that supports our academic mentors' success is that the item "I would prefer meetings be chaired by faculty members" received a mean score of 2.84. This finding suggests that our participants benefited sufficiently from their journal club experience while being supervised by student academic mentors. Furthermore, we believe that having this responsibility as a pregraduate medical student markedly improves leadership abilities. In addition, to handle this level of responsibility, our academic mentors had to thoroughly read the literature and internalize the particular topic, which significantly contributed to their medical and academic knowledge.

Learning necessitates an understanding of the subject matter, a willingness to put forth effort in studying, and the ability to control one's education [9]. According to SDT, humans naturally tend to develop self-directed and autonomous behavior regulation [13]. Because motivation is the primary energy that drives learning, SDT is applicable at all levels of education, including our journal clubs [14]. The findings show that intrinsic motivation is linked to student achievement and well-being [15]. The students in our journal clubs already had an extrinsic motivation, obtaining a certificate, which is an essential aspect of learning, describing the psychological state apparent when individuals are driven to acquire outcomes apart from the pleasure innate in the behavior itself [15,16]. In addition to this

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extrinsic motivation, we hoped to increase our participants' intrinsic motivation by giving them autonomy, which we believe positively impacted their successful presentations and general journal club experience.

Our study is not without limitations. First, the number of participants is insufficient to draw general conclusions. Perhaps beginning advertising earlier and more broadly could be beneficial in increasing the number of participants. However, as aforementioned, we do not intend to increase the number of participants in a particular journal club since participants were comfortable with the existing number. Instead, to accommodate more participants, the number of journal clubs should be increased. Second, since we do not have participant data to compare before and after implementation of the journal club, the survey only questioned participants' perspectives rather than providing objective results. To overcome this obstacle in the future, participants should be evaluated in terms of academic knowledge such as literature searching and database usage, as well as the presentation of an academic paper before the first meeting and after the last meeting.

Future Directions

As a society, we intend to continue our journal club for years to come. Even though medical education in Turkey is scheduled to be held face-to-face for the upcoming academic year, we intend to organize our journal club virtually for the upcoming academic year to minimize the COVID-19 risk and maintain the multi-institutional nature of our journal club. For this reason, to assess participants' attitudes toward "online" journal clubs for the next year, one of the Likert-scale items was "I would prefer online journal club meetings when the medical education becomes in person again," which resulted in a mean score of 3.96, indicating that the majority of our participants were pleased with the online format.

Given the short time between the announcement and the application deadline, there were more applicants than we expected. We intend to begin advertising for the upcoming academic year much earlier and increase the number of journal clubs, allowing us to contribute to the education of many more medical students whose institutions do not offer journal clubs.

Asynchronous Twitter journal clubs, in which participants contribute via tweets over a set period, have existed for some time, creating a diverse global forum for discussion [17,18]. We plan to implement an asynchronous Twitter journal club while keeping the synchronous format, allowing us to run a global journal club while also effectively advertising our journal club. If our asynchronous format can be successful, perhaps our synchronous format will become international, allowing medical students from all over the world to participate, particularly those whose medical schools do not provide such opportunities.

Conclusion

In a time of crisis that isolated medical students from hospitals and universities, our journal club facilitated continued interaction between medical students by providing a platform for academic discussions. During the pandemic, students from all over Turkey regularly attended our club, which reduced social isolation and increased cross-institutional interaction. Our survey revealed that our participants were pleased with our journal club, which makes us very proud given that the club is entirely student-run. This experience, we believe, demonstrated that medical students can run a journal club on their own, and we hope that this paper serves as a guide for other organizations as they plan their journal clubs.

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Conflicts of Interest

None declared.

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Abbreviations

IUC: Istanbul University-Cerrahpasa
SDT: self-determination theory

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Original Paper

Technology Literacy in Undergraduate Medical Education: Review and Survey of the US Medical School Innovation and Technology Programs

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Abstract

Background: Modern innovations, like machine learning, genomics, and digital health, are being integrated into medical practice at a rapid pace. Physicians in training receive little exposure to the implications, drawbacks, and methodologies of upcoming technologies prior to their deployment. As a result, there is an increasing need for the incorporation of innovation and technology (I&T) training, starting in medical school.

Objective: We aimed to identify and describe curricular and extracurricular opportunities for innovation in medical technology in US undergraduate medical education to highlight challenges and develop insights for future directions of program development.

Methods: A review of publicly available I&T program information on the official websites of US allopathic medical schools was conducted in June 2020. Programs were categorized by structure and implementation. The geographic distribution of these categories across US regions was analyzed. A survey was administered to school-affiliated student organizations with a focus on I&T and publicly available contact information. The data collected included the founding year, thematic focus, target audience, activities offered, and participant turnout rate.

Results: A total of 103 I&T opportunities at 69 distinct Liaison Committee on Medical Education–accredited medical schools were identified and characterized into the following six categories: (1) integrative 4-year curricula, (2) facilitated doctor of medicine/master of science dual degree programs in a related field, (3) interdisciplinary collaborations, (4) areas of concentration, (5) preclinical electives, and (6) student-run clubs. The presence of interdisciplinary collaboration is significantly associated with the presence of student-led initiatives (P=.001). “Starting and running a business in healthcare” and “medical devices” were the most popular thematic focuses of student-led I&T groups, representing 87% (13/15) and 80% (12/15) of respondents, respectively. “Career pathways exploration for students” was the only type of activity that was significantly associated with a high event turnout rate of >26 students per event (P=.03).

Conclusions: Existing school-led and student-driven opportunities in medical I&T indicate growing national interest and reflect challenges in implementation. The greater visibility of opportunities, collaboration among schools, and development of a centralized network can be considered to better prepare students for the changing landscape of medical practice.

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KEYWORDS

curricular development; medical innovation; medical technology; student engagement

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Introduction

The intersection of technology and medicine has continuously transformed health care delivery [1-3]. The medical applications of advancing technologies include the use of deep learning algorithms to power diagnostics [4], automated robotics to perform minimally invasive procedures [5], and computational genomics to inform personalized treatment plans [6]. In 2020, social distancing limitations due to COVID-19 catalyzed unprecedented developments in digital health [7-9]. From video consultation platforms to home testing kits and wearable sensors, patients have been increasingly exposed to a digitally driven health care model [10,11]. The breadth of personal health data that are available to patients is larger than ever before [12,13]. However, physicians are facing an increasing need to guide patients in correctly interpreting these data as well as communicate relevant implications of technology to patients. Moreover, technology literacy in medicine, that is, a basic understanding of how new technologies work and how they can be integrated into more patient-centered and efficient health care delivery systems, may allow for more effective interdisciplinary collaboration with experts in other fields to address clinical needs in innovative ways [14,15].

No matter the objective of an individual physician, speaking the language of technology should be learned during undergraduate medical education—the earliest years of one's training prior to the completion of an MD degree [16-18]. Some US medical schools have begun to approach the integration of technology into medical education [19-23]. However, a prior study of formal curricular programs in innovation and entrepreneurship demonstrated the lack of any formal competency models or frameworks among institutions working on this challenge [24]. Historically, medical schools have been able to adapt to health care workforce needs by providing students in training with new areas of knowledge. For example, recognizing that a patient's health is part of a broader social and environmental context facilitated the integration of behavioral and social sciences into medical education. These changes were aimed at enabling students to better understand epidemiology, mental health, and social determinants of health [25,26]. Although integrations like these are still being refined, they can offer an implementation framework that new curricular developments can follow. A remaining challenge will be developing consensus on standards for teaching students about emergent technology. Discussions about clinical applications and implementation are somewhat speculative, as there are less supporting data than what physicians are accustomed to, and requirements differ based on location and specialty.

Medical education has historically had to balance the need for standardization with the benefits of ingenuity and diverse methodologies [27]. Due to the novelty of technology integration, it may be premature to pursue standardization before understanding the approaches that have been tried and the outcomes that they have produced. Herein, we identify and analyze the innovation and technology (I&T) opportunities available at US allopathic medical schools and discuss thematic trends to support the future development of I&T curricula. Compared to the traditional definition of innovation and entrepreneurship, which largely focuses on business and economics, we concentrated on I&T. Our analysis provides a more expansive view on the diverse formats of learning opportunities, including formal curricula as well as extracurricular electives and initiatives. This study aims to quantify and detail the existing I&T opportunities available to medical students at US medical schools to provide insight for future curricular development directions.

Methods

The data collection process consisted of a combination of public internet searches and the collection of survey responses from student organizations across the country. Surveys were conducted in June 2020 and asked for objective information, including club characteristics, types of activities, and target audiences.

Ethics Approval

Since no individual information or opinions were collected, this study did not meet the requirements for a human subject review, per our institutional review board's protocol.

Review of Current Programs

An internet search of all Liaison Committee on Medical Education–accredited US allopathic medical schools [28] was conducted to identify any relevant curricular and extracurricular programs that were offered. The key search terms were *medical education*, *technology*, *engineering*, *innovation and entrepreneurship*, *curriculum*, and *student activities/organizations*. The inclusion criteria were defined as (1) programs officially sanctioned by a medical school (ie, programs that have been recognized by school administrations and other publicly affiliated sources) and (2) programs that mentioned at least 1 of the following in their mission statement: (1) applying engineering research and existing technologies in medicine or (2) inventing and designing technological solutions in medicine. The exclusion criteria included programs without a significant technical or innovative component. These programs may (1) have a primary focus on other topics, such as business, economics, leadership, health policy, and health information management; (2) include a scholarly component on any topic of choice but do not provide a specific focus on I&T; and (3) be doctorate of medicine and philosophy (MD-PhD) programs that undergo a separate application and admission process.

Survey on Student-Led Initiatives

The initial abstraction of public data indicated a lack of organized and publicly available information on student-led I&T organizations and activities. We designed a short, 9-question survey for student groups by using the web-based program Typeform (Typeform SL). The survey was sent electronically to all identified school-affiliated I&T groups whose contact information was publicly available. The survey consisted of 8 total questions that inquired about the (1) founding year, (2) thematic focus, (3) target audience, (4) activities offered, and (5) participant turnout rate. The responses collected contained only objective information and involved no subjective data. Recorded data were securely stored in a protected spreadsheet that was exported from Typeform.

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Data Analysis

The data analysis included both aggregated data from the internet search and completed survey responses. Programs that met the inclusion and exclusion criteria were analyzed and classified into 6 categories based on program characteristics. The geographic locations of programs were noted for regional relationships. Survey results and publicly available information, either from the clubs' own websites or from the schools' student activity websites, were synthesized. A thematic analysis was performed and included the following information about each program: the number years since its founding, its mission, its target audience, events and activities, and the medical student turnout rate. A statistical analysis was conducted on survey data by using SPSS version 26 (IBM Corporation) for macOS. A chi-square test of independence was performed for any associations between student-led initiatives and other curricular opportunities.

Results

Review of Current Programs

Our investigation of existing programs found varying degrees of curricular integration and various durations and target audiences. A total of 103 programs at 69 distinct schools were identified to have at least 1 program that met our inclusion and exclusion criteria. Further, 6 categories were determined based on the level of administrative and student involvement of these programs (Table 1). Programs were further analyzed by geographical region (Figure 1 and Table 2). The highest ratios of the number of available programs to the number of medical schools were found in the northeast (32 programs to 36 schools; ratio: 0.89) and west (16 programs to 24 schools; ratio: 0.67). The regional subdivision with the highest program density was New England (13 programs to 10 schools; ratio: 1.30). Texas offered the greatest number of programs (8 programs to 12 schools; ratio: 0.67), followed by California (7 programs to 13 schools; ratio: 0.54) and New York (7 programs to 15 schools; ratio: 0.47). Interestingly, 16 states were identified as having 0 I&T programs available to students at their medical schools, and 14 of these states have only 1 or 2 allopathic medical schools. Further, 12 states offer more than 3 programs, with Rhode Island having the greatest number of programs per medical school (3:1 ratio).

Student-led clubs and initiatives were the most common type of opportunity available to students, representing 44.7% (46/103) of the total programs. Curricular tracks or areas of concentration were the next most common type (21/103, 20.4%), followed by interdisciplinary collaborations (14/103, 13.6%), dual degree programs in a related field (12/103, 11.7%), and noncredited elective courses (6/103, 5.8%). Of note, there are 4 special programs with a 4-year integrated curriculum (4/103, 3.9%). Table 3 shows that interdisciplinary collaborations were the only type of program that was significantly associated with the presence of student initiatives (P=.001; χ^2_1=10.6).

Table 1. The six identified innovation and technology program categories and descriptions of each category.

Category	Description of category	Number of programs (N=103)
4-year integrated programs	The programs exhibit longitudinal themes that are integrated across all 4 years. Admission into each program is separate from admission into the general MD degree program. Other shared characteristics include a graduating project requirement and significant accompanying research involvement. Table 3 provides a more comprehensive analysis of these programs.	4
MD/MS dual degree programs	Facilitated, and often accelerated (5 years or fewer), dual degree programs offering MS degrees in biomedical engineering or health technology.	12
Interdisciplinary collaborations	Institutes and incubators aimed at encouraging collaboration across different schools within the greater institution.	14
Tracks or areas of concentration	The programs extend over multiple semesters, with final completion being noted in the dean's letter or official transcript. Many require 1 or more courses and a research component to supplement the regular medical curriculum.	21
Noncredited elective courses	Semester-long courses that are available to medical students for enrichment purposes. They are not credited or noted on the official transcript.	6
Student-led clubs	Student-run organizations that host regular events for the student body.	46

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Figure 1. A map representation of innovation and technology programs across the major geographical regions based on the US Census. AOC: area of concentration.

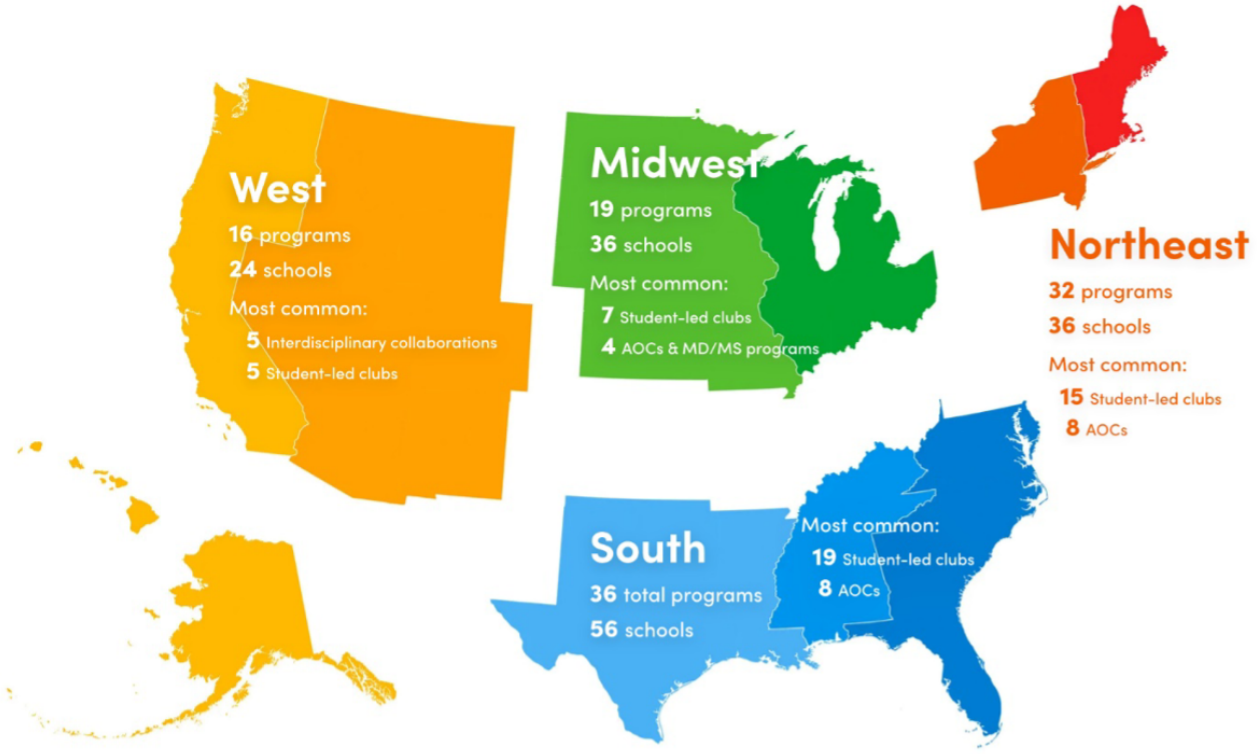

Table 2. Overview of innovation and technology programs at accredited US allopathic medical schools.

Characteristic	West region[a]	Midwest region[b]	Northeast region[c]	South region[d]	All regions
4-year integrated programs, n	1	1	1	1	4
MD/MS dual degree programs, n	3	4	1	4	12
Interdisciplinary collaborations, n	5	2	4	3	14
Concentration tracks or areas of concentration, n	1	4	8	8	21
Noncredited elective courses, n	1	1	3	1	6
Student-led clubs, n	5	7	15	19	46
Total programs, n	16	19	32	36	103
Total schools, n	24	36	36	57	153
Ratio of the number of programs to the number of schools	0.67	0.53	0.89	0.63	0.67

[a]States per region: Washington, Oregon, California, Montana, Idaho, Wyoming, Nevada, Utah, Colorado, Arizona, and New Mexico.

[b]States per region: North Dakota, South Dakota, Nebraska, Kansas, New Mexico, Iowa, Missouri, Wisconsin, Illinois, Michigan, Indiana, and Ohio.

[c]States per region: New York, Pennsylvania, New Jersey, Vermont, New Hampshire, Maine, Massachusetts, Connecticut, and Rhode Island.

[d]States per region: Oklahoma, Texas, Arizona, Louisiana, Mississippi, Alabama, Tennessee, Kentucky, West Virginia, Virginia, Maryland, Delaware, North Carolina, South Carolina, Georgia, and Florida.

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Table 3. Associations among program categories based on the existence of student initiatives.

Program	Presence of student-led clubs			Chi-square (*df*)	*P* value
	Yes, n	No, n	Total, n		
4-year integrated program				—[a]	.58[b]
Yes	2	2	4		
No	44	105	149		
Total	46	107	153		
Concentration track or area of concentration				1.4 (1)	.23
Yes	9	13	22		
No	37	94	131		
Total	46	107	153		
Noncredited elective course				—	.37[b]
Yes	3	3	6		
No	43	104	147		
Total	46	107	153		
MD/MS dual degree program				0.2 (1)	.69
Yes	3	9	12		
No	43	98	141		
Total	46	107	153		
Interdisciplinary collaboration [c]				10.6 (1)	.001
Yes	10	5	15		
No	36	102	138		
Total	46	107	153		

[a]Not available.

[b]Due to the small sample size, we used the *P* value of a Fisher exact test instead of a chi-square test.

[c]Significant at the $P<.05$ level.

Survey on Student-Led Initiatives

Summary of Survey Results

Of the 46 total student groups, 33 had publicly available contact information and were invited to complete the survey through email. We recorded 15 completions, indicating a 45% (15/33) response rate. The results are summarized in Multimedia Appendix 1.

Age Since Founding

The results from the survey and publicly available information yielded a total of 26 known founding years. Of the 26 student-led initiatives, 20 (77%) were founded in or after 2016, and 8 (31%) were founded in or after 2018. Figure 2 illustrates the chronological growth of these initiatives.

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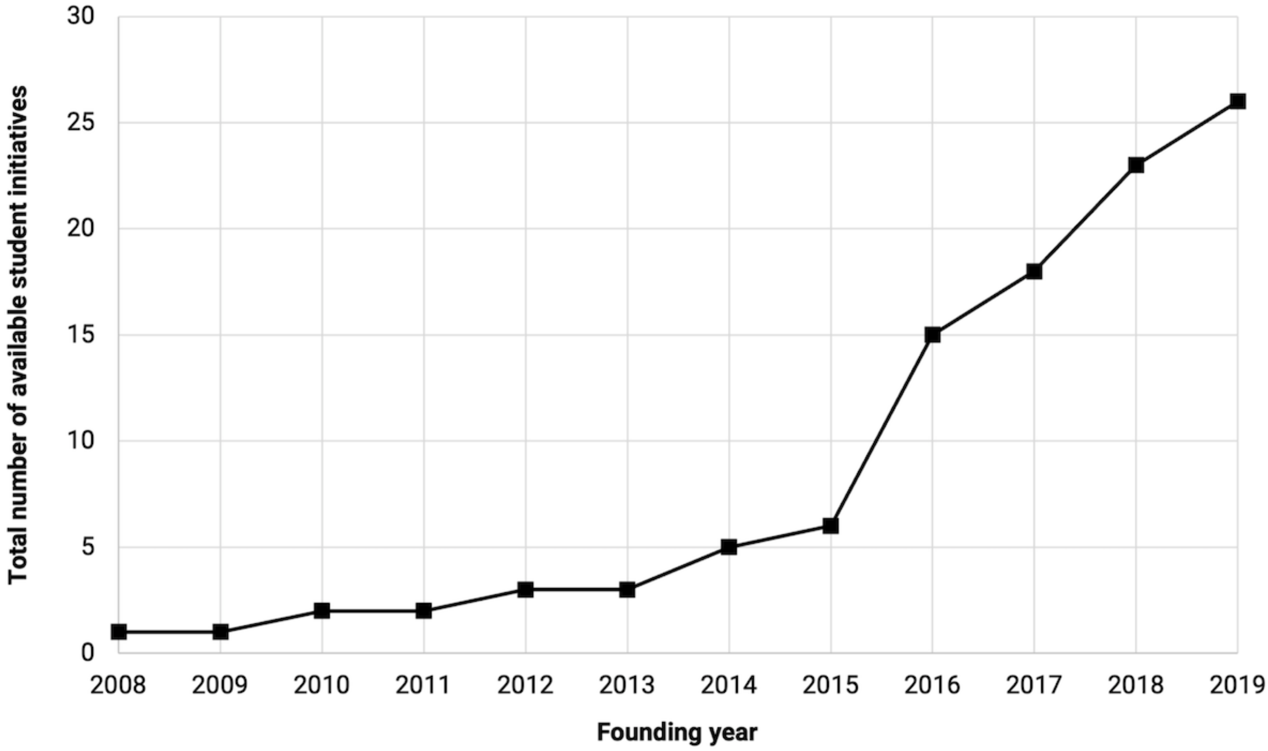
Figure 2. Student-led initiatives sorted based on the founding year. Founding years were either self-reported on our survey or determined based on publicly available information on medical school websites and internet archives.



Mission

Among the 15 surveyed organizations with completed responses, student groups' goals included "starting and running a business in healthcare" (13/15, 87%), "medical devices" (12/15, 80%), "helping students under the challenges associated with bringing ideas to market" (11/15, 73%), and "digital health" (10/15, 67%). A word cloud of club mission statements showed that *technology* (39 instances), *innovation* (38 instances), and *medicine* (30 instances) were the most common words mentioned (Multimedia Appendix 2).

Activities and Events

Talks hosted by either biotechnology and health industry representatives or faculty and physician speakers are the most common form of activity for student groups (13/15, 87%). Other commonly offered activities include "collaboration with schools of other disciplines" (11/15, 73%) and "connecting students to opportunities & resources" (11/15, 73%).

Turnout Rate and Audience

Of the 15 surveyed organizations, 12 (80%) indicated that >10 people routinely attended events. Of these 12 groups, 5 (42%) reported the attendance of between 26 and 50 people, and 1 (8%) reported the attendance of between 51 and 75 people. The events mostly targeted medical students in preclinical years (groups: 13/15, 87%) and graduate students (groups: 10/15, 67%). A minority of organizations (groups: 5/15, 33%) directly involve medical students in clerkship years, resident physicians, attending physicians, and engineering faculty. "Career pathways exploration for students" was the only type of activity that was significantly associated with a high event turnout rate of >26 students per event (P=.03; odds ratio 0.38, 95% CI 0.15-0.92).

Discussion

Current State of I&T Programs

We found a total of 103 officially sanctioned I&T programs that were available to medical students at the time of this study. These programs span 6 levels of curricular integration, ranging from student-led initiatives to fully integrated MD degree curricula. Geographically, the highest concentration of programs per school are in the northeastern and western regions, particularly in states with a high number of medical schools that highly engage with technology industries [29]. One example of a fully integrated program is EnMed—a tripartite collaboration among Texas A&M's College of Engineering, College of Medicine, and Houston Methodist Hospital—which integrates "innovation rotations" with researchers, collaborators, and industry partners in the medical technology field within a 4-year MD degree program [30]. However, full curriculum integration is less common. The majority of the identified programs were student-run initiatives (46/103, 44.7%). From 2015 to 2019, the number of these initiatives has seen exponential growth, with greater than a striking 400% increase (6 groups to 26 groups). The majority of student groups emphasized the thematic focuses of health care entrepreneurship (13/15, 87%) and medical devices (12/15, 80%), which were most often supported by events hosted by industrial representatives and faculty speakers. In addition, 40% (6/15) of student groups reported having >26 attendees, demonstrating high student body engagement relative to the average national class size [31].

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Call for Action: Increased Interest in I&T Among Medical Students

New generations of medical students have strong interests in the technological advancements in medicine and consider these areas of growth to be essential to future clinical practice [32]. Prior survey studies have demonstrated a significant interest in medical technology and informatics among medical students and residents [33], particularly among those intending to pursue surgical specialties [34]. In another survey study, MacNevin et al [35] showed that 79.2% of second-year medical students were "technology ready," indicating their propensity to use new technology. However, most students do not receive formal education or training in this area [36]. Our results suggest that students are taking initiative to fill unmet needs at their respective schools, highlighting the importance of developing I&T-based education programs as part of our call for educational reform [37].

Existing literature demonstrates both the benefits and challenges associated with student-led initiatives. There is evidence of student-run electives and journal clubs resulting in positive short-term outcomes [38-40]; however, medical schools need to focus more on equipping students with proper skills and resources for effecting long-lasting advancements [41]. One major challenge faced by student-led groups is recruiting and transitioning leadership between successive class years, which results in continuity gaps in provided activities from year to year. This lack of continuity may be addressed by medical school administrations taking more responsibility for their student-led groups and by introducing a structure that supports interdisciplinary collaboration. In fact, our analysis shows a significant correlation between interdisciplinary collaborations within students' home institutions and turnout rates for student-led activities (P=.001). Students may find it easier to pursue projects and consider the future integration of innovation into their medical careers when they are able to collaborate with colleagues who have complementary skill sets, such as engineering and business skill sets [42-44]. This further reinforces the importance of administrative initiative in supporting students' interests and activities.

Future Directions: Challenges and Propositions

Geographical Barriers to External Support

Our review identifies several challenges in the implementation of I&T-focused initiatives in US allopathic medical schools. Our geographical analysis correlates the density of available programs with their proximity to biotechnology hubs, suggesting that regional economic factors and the availability of external support may be associated with students' and faculties' exposure to I&T outcomes, further encouraging interest and investment [45]. However, areas with a low biotechnology entrepreneurship presence may produce fewer physicians who are equipped to take advantage of new clinical developments, leading to disparities in future care delivery and suggesting the importance of developing I&T initiatives in these areas. When considering efforts for introducing technological concepts into medical education, McCoy et al [46] suggest distinguishing between information that physicians must know for daily practice and information that they should know for innovation advancement; the curricular components of such efforts should target the former, and robust extracurricular programs should target the latter. Given the geographic distribution of programs across the country, well-equipped and well-resourced institutions may act as examples for supporting and modeling curriculum development and developing best practices.

Needs Assessment for Curricular Development

This review identifies great variation in the types of opportunities being offered to students. Hence, gaining a better understanding of the efficacy and drawbacks of each approach is important to achieving improved outcomes, as previously proposed by Chan and Zary [47] in their review of implementing artificial intelligence in medical education. Echelard et al [48] have also proposed the implementation of new courses and rotations, mentorships, and expert invitations to medical schools. Rigorous assessments of program outcomes, such as students' familiarity with medical technology concepts or the potential rise in student- and physician-driven inventions and start-ups from proactive institutions, may be valuable downstream end points. Analyses of what practicing physician innovators identify as their needs may result in the creation of a more balanced basis for, as well as increased student interest in, defining competencies in formal curricula. In the interim, offering track programs or ancillary degrees and certificates may help with the transition to the eventual curricular reform [49]. Bringing new technologies into everyday classrooms and clinical settings can help students familiarize themselves with novel operating skills and can foster the appreciation for innovative design and problem solving [50,51].

Future studies may benefit from using Association of American Medical Colleges data from the Curriculum Reports and FACTS data sets. The former may provide insight into which schools are currently pursuing curriculum changes, which competency criteria are receiving greater prioritization in these changes, and what types of instructional methods are being applied to implement these changes. FACTS data may provide insight into the backgrounds of medical school applicants and matriculants, which may help to determine whether increasing proportions of students with engineering or business backgrounds are associated with the rapid increase in the student-led initiatives reported in our study.

Limitations

This study exhibits several limitations. First, it relied on publicly available information. Due to possible delays between the creation of initiatives and formal publicity on the web, as well as the inherent private nature of certain types of initiatives, our study may have missed more recent efforts. This may have resulted in an underestimation of recently founded programs, especially those from schools with less frequent website updates. However, one benefit of our approach is that we were able to provide a more accurate representation of how prospective trainees and collaborators are able to discover programs, as they are generally limited to publicly available information. Future studies can deliver surveys to individual medical schools to obtain a more accurate count of the number of I&T programs that each school offers. Additionally, the development of a centralized database of opportunities and joint conferences may

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facilitate greater discoverability within the medical education community.

A second limitation was the challenge of surveying student organizations through publicly available contact information. In some cases, publicly available contact information was unavailable or outdated, resulting in only 33 of the 46 identified programs being sent surveys and contributing to our survey response rate. As in all survey studies, limitations in the generalizability and inflexibility of multiple-choice responses apply to our study. Our survey may be biased toward more active student organizations who provide contact information publicly and routinely respond to inquiries. Inactive student organizations may have low levels of student engagement and few organized activities; therefore, these organizations may be underrepresented in our results. Future studies may mitigate this problem by engaging medical school activity coordinators, who may provide more recent contact information and status information on club inactivity.

Conclusions

New technologies and innovations are transforming medicine and clinical care. Efforts in exposing students to technology and innovation in medical school will prepare students for the changing landscape of medical practice. Our review of existing opportunities indicates both the growing interest in introducing trainees to medical I&T and the current challenges in integrating formalized curricular changes. Immediate and tangible future directions include increasing the visibility of current and future opportunities, achieving greater collaboration among schools, and establishing a national competency curriculum as well as a centralized platform that interested students and educators can use to share experiences.

Acknowledgments

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Conflicts of Interest

None declared.

Multimedia Appendix 1
Student organization survey items and responses.
[DOCX File , 18 KB - mededu_v8i1e32183_app1.docx]

Multimedia Appendix 2
Word cloud generated from student organizations' mission statements.
[PNG File , 170 KB - mededu_v8i1e32183_app2.png]

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Abbreviations

I&T: innovation and technology

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Letter to the Editor

Techniques to Teach Students Effectively Using Telemedicine. Comment on “Incorporating Medical Students Into Primary Care Telehealth Visits: Tutorial”

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KEYWORDS

medical student; education; primary care; telehealth; video visits; internal medicine; medical education; teleconsultation; digital health; COVID-19; teaching; telemedicine; clerkships

We read the findings of Balaji and Clever [1] with great interest, which highlight a successful approach to engaging students with patients on community-based placements during a challenging public health crisis. While we acknowledge the limited sample size of this study, our experience as senior clinical medical students also reflects the merits of telemedicine for continuing medical education [2] where direct patient care has been limited.

We endorse the suggested recommendations as highly effective in practice based on our experience. We wish to propose further recommendations from our personal observations. First, prior to a consultation, providing students access to the patient’s presenting complaint and their medical history leads to a focused consultation. Patients often redirect clinicians to check their records when asked questions about their background. Accessing patient details beforehand can save valuable time and facilitate rapport building. Furthermore, where students have just started their placement or clerkship, or clinicians are unfamiliar with their assignee, a “see one, do one, teach one” or “knows how, shows how, does” experiential learning approach is recommended [3,4]. In lieu of teaching, students will hopefully be able to conduct history-taking autonomously, with minimal supervision. First, observing an interaction can build familiarity and orientation with software, and can help set the clinicians’ expectations and reduce student anxiety. Next, observing the student interaction allows the clinician to allay any safety concerns while suggesting improvements in manner and approach.

We suggest an alternative approach to enhance the value students can provide to the general practitioner (GP). We propose having students call patients during a fixed time in the morning and discussing their presentations after appointments are scheduled; this includes a differential diagnosis and proposed management with the GP as well. In our experience, many patients are available and amenable to being called earlier than their appointment time to speak with a student once assured they will be speaking to a doctor later. GPs can then call the patient to confirm the history, ask additional questions, and finalize a management plan, including assessing the need for an in-person follow-up.

Telemedicine has been rapidly adopted as a means of providing remote care, protecting patients and health care providers from direct infection transmission. Since its integration into daily practice, the convenience and cost savings for both patients and practitioners indicate that it is unlikely to disappear [5]. It is one successful avenue to continue students’ education and

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provide opportunities for engagement in patient care, in light of the disruption to clinical placements and face-to-face teaching. Digital competence and familiarity have become a vital part of the medical curriculum, meaning that students need to be trained to provide high-quality care through such technologies.

Conflicts of Interest

None declared.

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Abbreviations

GP: general practitioner

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Letter to the Editor

Authors' Reply to: Techniques to Teach Students Effectively Using Telemedicine. Comment on "Incorporating Medical Students Into Primary Care Telehealth Visits: Tutorial"

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Abstract

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KEYWORDS
medical student; education; primary care; telehealth; video visits; internal medicine; medical education; teleconsultation; digital health; COVID-19; teaching; telemedicine; clerkships

We appreciate the comments by Kandola and Minhas [1] on our paper [2] and their perspective on telemedicine as senior medical students. We wanted to comment on the additional recommendations the authors suggested.

See One, Do One, Teach One

We agree with the approach of first observing visits to understand the flow and format; then conducting a visit with the preceptor in the room for immediate feedback and support if needed; and finally, conducting visits independently, then presenting an assessment and plan to the preceptor outside the room. Importantly, discussing the flow prior to the clinic day sets expectations, allows the student to prepare appropriately, and permits for structured feedback to be given [3,4]. As described by Dornan et al [3], the student can progress through passive observation to active observation to participation to appropriate independence. Teleclinics are perfect opportunities for students to practice and advance through each of these stages.

Early Patient Calls

In this approach, the student would call patients in the morning and formulate a concise history, assessment, and plan. Some considerations for this model are whether patients are available in the morning. Patients often choose telemedicine appointments to reduce travel time and fit in appointments between busy work schedules [5,6]. These patients may not be amenable to two encounters for one visit. However, permission could be established prior to students contacting the patients.

An additional consideration is whether telemedicine clinics should mirror outpatient clinics. In an in-person clinic, the student would see patients independently and quickly formulate their thoughts to present to their preceptors during each patient visit. The immediate feedback from the preceptor is lost in this telemedicine clinic format. However, calling patients early then presenting these batched visits to the preceptor later could be used at the start of a telemedicine rotation. This way, students

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have more time with each patient early on and can aim to transition into the telemedicine clinic with their preceptor to conduct the first portion of the visit.

As medical institutions are becoming more comfortable with and adept at telemedicine, there are multiple successful ways to engage learners. With the increased use of telemedicine, it is imperative learners are exposed to this platform to deliver care early in their training.

Conflicts of Interest

None declared.

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