frontiers | Research Topics

Impact of technology on human behaviors in medical professions education

Edited by
Muhammad Azeem Ashraf, Jinbo He and Samson Maekele Tsegay

Published in
Frontiers in Medicine

ISSN 1664-8714
ISBN 978-2-8325-6025-9
DOI 10.3389/978-2-8325-6025-9

About Frontiers

Frontiers is more than just an open access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

Frontiers journal series

The Frontiers journal series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the *Frontiers journal series* operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

Dedication to quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews. Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view. By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the *Frontiers journals series*: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area.

Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers editorial office: frontiersin.org/about/contact

Impact of technology on human behaviors in medical professions education

Topic editors

Muhammad Azeem Ashraf — Hunan University, China

Jinbo He — The Chinese University of Hong Kong, Shenzhen, China

Samson Maekele Tsegay — Anglia Ruskin University, United Kingdom

Citation

Ashraf, M. A., He, J., Tsegay, S. M., eds. (2025). *Impact of technology on human behaviors in medical professions education*. Lausanne: Frontiers Media SA.

doi: 10.3389/978-2-8325-6025-9

Table of contents

frontiers | Frontiers in Medicine

TYPE Editorial
PUBLISHED 07 February 2025
DOI 10.3389/fmed.2025.1546296

OPEN ACCESS

EDITED AND REVIEWED BY
Lynn Valerie Monrouxe,
The University of Sydney, Australia

*CORRESPONDENCE
Samson Maekele Tsegay
✉ samson.tsegay@aru.ac.uk

RECEIVED 16 December 2024
ACCEPTED 27 January 2025
PUBLISHED 07 February 2025

CITATION
Ashraf MA and Tsegay SM (2025) Editorial: Impact of technology on human behaviors in medical professions education.
Front. Med. 12:1546296.
doi: 10.3389/fmed.2025.1546296

Editorial: Impact of technology on human behaviors in medical professions education

Muhammad Azeem Ashraf[1] and Samson Maekele Tsegay[2]*

[1]Institute of Educational Sciences, Hunan University, Changsha, China, [2]School of Education, Anglia Ruskin University, Cambridge, United Kingdom

KEYWORDS

technology, medical education, medical technology (Med-Tech) innovations, educational technology research, technology in a classroom, technology in medical education

Editorial on the Research Topic
Impact of technology on human behaviors in medical professions education

The Research Topic focuses on the impact of technology on human behaviors in medical sciences teaching and learning. It also explores the effect of social, psychological, and other factors on the use of technology in medical education. In so doing, the Research Topic focuses on the integration of technology and the role of human behaviors in improving the teaching and learning process of medical education. Technology has revolutionized education by allowing teachers and students to establish new ways of teaching and learning (1, 2). It has transformed the delivery of knowledge and the behaviors and attitudes of educators and learners. Integrating advanced tools, such as virtual reality (VR), artificial intelligence (AI), and online learning platforms, has improved how medical students and professionals acquire skills, interact with patients, and engage with peers. Interactive technologies like simulation-based learning and VR allow students to engage in realistic scenarios without risk to real patients. Digital tools such as shared virtual workspaces and cloud-based platforms enable students to collaborate on projects regardless of their geographical location. Digital platforms such as Massive Open Online Courses (MOOCs) and online medical databases provide professionals with instant access to the latest research and clinical guidelines. This accessibility promotes continuous learning habits among medical practitioners, encouraging them to stay updated and adapt to evolving practices.

Technology has also impacted collaboration in medical education. This fosters teamwork and communication skills that are essential in healthcare settings. Moreover, technology encourages interdisciplinary learning, as students from different fields can easily participate in joint training sessions, enhancing their ability to work in diverse teams. In addition to its support in improving teaching and learning in medical education, technology has raised ethical questions that shape behaviors. For example, in the Research Topic, Alam et al. argued that, despite AI's immense potential for advancing healthcare and medicine, careful attention must be paid to ethical considerations. This suggests that using AI in diagnosis and treatment planning requires students to learn about data privacy, algorithm bias, and ethical decision-making. Ethical considerations associated with healthy/unhealthy use of technology in medical sciences are also related to human behavior. Hence, medical education must incorporate knowledge, skills, and attitudes to prepare students to navigate complex ethical landscapes.

The Research Topic consists of 11 articles examining technology's impact on medical education from different perspectivesThe articles included in the Research Topic can be categorized into three themes.

1. Digital identity and professionalism in medical profession education

The articles on this theme discuss the impact of technology on human behavior, especially the connection between technology and digital professionalism and psychological changes. Guraya et al., explored the modeling of digital identity and virtual engagement in the medical field, emphasizing mission-driven e-professionalism. They identified three key components: solidification, digitally cultural fitness, and shared agency. Moreover, Kitamura et al. used text mining techniques that analyze qualitative information with quantitative features to investigate how rehabilitation students' goals change during their first year at university. Overall, the articles highlight how technology affects the ethical identity and psychological changes of students.

2. Technology and instructional methods in medical profession education

Considering the multifaceted impact of technology on human behaviors in medical professions education, offering both opportunities and challenges, the Research Topic included articles that contribute to advancing knowledge on how technology impacts medical education through instructional methods. Delafontaine et al. conducted an observational retrospective monocentric study in a French physiotherapy school to examine the consequences of a blended learning program for musculoskeletal anatomy on student skills. Schievano et al. examined the effectiveness of a blended e-learning program, via the PhArmacoVIgilance Africa (PAVIA) training program, and its adaptation during the COVID-19 pandemic. Ashraf et al. examined the role of blended learning in improving medical students' academic performance through self-regulatory learning and technological competence. Chen et al. investigated the application effect of the online and offline mixed teaching mode in nursing practice teaching based on the Source Message Channel Receiver (SMCR) communication model. Sadiq et al. researched integrating technology-enhanced learning in medical education by introducing an E-Portal training program to allow health professions educators to learn essential skills for proficiently employing digital tools in instruction. The articles share the idea that technology affects the experiences of medical students, teachers, and professionals and thus students' learning.

3. Artificial intelligence in medical profession education

The articles of the Research Topic in this theme explore Artificial Intelligence in medical education, which helps to create awareness for the healthy use of technology. Alam et al. advocated the integration of AI tools in medical education, specifically learner-oriented AI tools, and proposed guidelines for medical students to use these tools. Wang et al. studied the relationship between social media-driven networks and job performance among primary healthcare professionals, highlighting knowledge sharing as a mediating factor. Ismail et al. explored non-verbal communication techniques (NVC) during online feedback sessions for communication skill activities in a medical education module and indicated its impact on conveying nuanced information. Du et al. proposed the ensemble model to show the role of AI in disease prediction for medical practitioners.

In conclusion, this Research Topic has explored the impact of technology on human behavior in medical professions education from various perspectives using different theoretical frameworks. The findings suggest that while technology fosters engagement, collaboration, and lifelong learning, it also requires a concerted effort to preserve essential human skills and attitudes, such as empathy and ethical reasoning. By embracing a balanced approach, medical educators can ensure that technology enhances, rather than diminishes, the humanistic aspects of medical practice. On a different note, it is important to question: how might technology impact medical professions education differently from other fields or disciplines?

Author contributions

MA: Writing – original draft, Writing – review & editing. ST: Writing – original draft, Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Ashraf MA, Tsegay SM, Meijia Y. Blended learning for diverse classrooms: qualitative experimental study with in-service teachers. *Sage Open.* (2021) 11:21582440211030623. doi: 10.1177/21582440211030623

2. Tsegay SM, Ashraf MA, Perveen S, Zegergish MZ. Online teaching during COVID-19 pandemic: teachers' experiences from a Chinese university. *Sustainability.* (2022) 14:568. doi: 10.3390/su14010568

frontiers | Frontiers in Medicine

TYPE Original Research
PUBLISHED 12 October 2023
DOI 10.3389/fmed.2023.1260416

OPEN ACCESS

EDITED BY
Samson Maekele Tsegay,
Anglia Ruskin University, United Kingdom

REVIEWED BY
Giacomo Rossettini,
University of Verona, Italy
Maria García Escudero,
Catholic University of Valencia San Vicente Mártir, Spain

*CORRESPONDENCE
Arnaud Delafontaine
✉ delafontaine@u-psud.fr

RECEIVED 17 July 2023
ACCEPTED 25 September 2023
PUBLISHED 12 October 2023

CITATION
Delafontaine A, Saiydoun G, Frigout J, Fabeck L, Degrenne O and Sarhan F-R (2023) Pedagogical impact of integration of musculoskeletal anatomy blended learning on physiotherapy education.
Front. Med. 10:1260416.
doi: 10.3389/fmed.2023.1260416

Pedagogical impact of integration of musculoskeletal anatomy blended learning on physiotherapy education

Arnaud Delafontaine[1,2,3,4]*, Gabriel Saiydoun[5,6,7,8,9], Jérôme Frigout[10], Laurent Fabeck[1], Olivier Degrenne[11] and François-Régis Sarhan[12,13]

[1]Université Libre de Bruxelles, Brussels, Belgium, [2]CIAMS, Univ. Paris-Sud., Université Paris-Saclay, Orsay, France, [3]CIAMS, Université d'Orléans, Orléans, France, [4]ASSAS, Ecole de Rééducation, Département international et Recherche, Villa Thoréton, Paris, France, [5]Unisurg, Paris, France, [6]Department of Cardiac Surgery, Henri Mondor University Hospital, Créteil, France, [7]Créteil, UFR Médecine-Pharmacie, University of Paris-Est Créteil, Créteil, France, [8]Biomedicale, IMRB, Inserm, Institut Mondor de Recherche Biomédicale, Faculté de Santé de Créteil, Institut Mondor de Recherche Biomédicale, Creteil, France, [9]Department of Cardiovascular and Thoracic Surgery, Pitié-Salpêtrière University Hospital, Assistance Publique-Hôpitaux de Paris-Sorbonne University, Paris, France, [10]I3SP Laboratory, Department of Sports Science and Physical Education, Université de Paris Descartes, Paris, France, [11]LIRTES, Université Paris-Est Créteil, Créteil, France, [12]Physiotherapy School, Centre Hospitalier Universitaire Amiens – Picardie, Amiens, France, [13]UR CHIMERE, Université de Picardie Jules Verne, Amiens, France

Background: In physiotherapy education, blended learning is recognized to be more effective compared to traditional teaching. The aim of this study was to assess the consequences of a musculoskeletal anatomy blended learning program on skills developed by students.

Methods: We conducted an observational retrospective monocentric study in a French physiotherapy school named "X." Ninety-two first-year students in the 2017–18 baseline group (students with traditional face-to-face learning), and ninety-eight first-year students and ninety-five second-year students in the 2018–19 and 2019–20 blended learning experimental groups was included. A success rate of the anatomy final written exam, defined by the percentage of students scoring 50% or above, was analyzed between 2017 and 2020. We also evaluated the pedagogical value of musculoskeletal e-learning and its usefulness for preparing the student for their anatomy final written exam at «X».

Results: We observed an improvement in the success rate of the anatomy final written exam between the 2017–18 baseline group, 2018–19 and 2019–2020 experimental groups during first (Kruskal–Wallis = 74.06, df = 2, $p < 0.001$) and second semester (Kruskal–Wallis = 173.6, df = 2, $p < 0.001$). We obtained a data survey and questionnaire response rate of 74% ($n = 89/120$) for the 2018–19 and 62% ($n = 72/116$) for the 2019–20 experimental groups. Concerning questionnaire response, they were no significant statistical difference between 2018–19 and 2019–20 experimental groups.

Conclusion: Blended learning could improve student success rate of the anatomy final written exam and learning of professional physiotherapy skills.

KEYWORDS

physiotherapy student, blended learning, traditional teaching, musculoskeletal anatomy, physiotherapy education

1. Introduction

1.1. Background

Physiotherapy education in France has transformed since 2015, shifting toward a university degree program (1, 2). Historically, physiotherapy schools were separate from universities and awarded a "Diplôme d'Etat de Masseur-Kinésithérapeute (DEMK)" after a three- or four-year program. The new system is a five-year university-based program (1, 3, 4) (Figure 1), starting with a common year of university alongside other healthcare programs, followed by specialized physiotherapy education.

During the first year, students study general courses, including chemistry, physics, biochemistry, and others (5, 6). Second-year admission is based on an entrance exam for physiotherapy, medicine, dentistry, pharmacy, or midwifery. Years two to five are taught at physiotherapy schools, which collaborate with universities to establish conditions for earning European Credits (ECTS) and a Master's degree.

The healthcare reform facilitated e-learning adoption, a popular and efficient teaching mode in the medical field, especially amid the coronavirus disease of 2019 (COVID-19) pandemic (7, 8).

In fact, Rossettini et al. (9, 10) underlined that, in post-COVID-19 period, physiotherapy educators had to implement digital education into entry-level physiotherapy education, especially to deal with social inequality and evaluation of students.

For instance, "X" physiotherapy school in the Paris region had to develop innovative ways to teach musculoskeletal anatomy with limited hours alongside medicine students at Paris-Saclay University's Faculty of Medicine (11).

E-learning, particularly blended learning, has become the standard in medical and physiotherapy education [(12–16); Rossettini et al. (9, 10); (17, 18)]. Blended learning enhances learning outcomes, satisfaction, and attitudes among physiotherapy students (19–21) but may not significantly improve clinical practice (22, 23).

E-learning improves inter-professional collaboration among medical, nursing, physiotherapy, and occupational therapy students (24) and enhances anatomy learning when combined with traditional teaching methods (25–27). It benefits students who require visual and kinesthetic learning, like physiotherapists (28). However, despite of these benefits, a recent systematic review (29) shows that most studies used non-validated tools in order to quantify the improvement of digital health competencies due to digitalization among healthcare professionals.

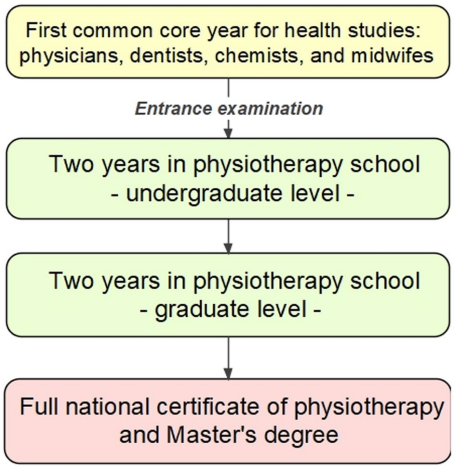


FIGURE 1
Physiotherapy program over five years: a first, common year is followed by 4 years of specialization in physiotherapy.

1.2. Objectives

In "X" physiotherapy school, e-learning was introduced to complement traditional classroom-based anatomy courses. This study aims to assess the impact of musculoskeletal anatomy blended learning on final exam performance compared to traditional teaching methods. The hypothesis is that blended learning will lead to improved success rates (30).

Overall, the healthcare reform in France has paved the way for the integration of e-learning in physiotherapy education, enhancing learning experiences and academic outcomes (31, 32).

2. Materials and methods

2.1. Study design

We used data from a monocentric observational retrospective study on physiotherapy students. The STROBE guidelines were adhered to by the methodology of the article (33).

2.2. Setting

The study was conducted in a French public physiotherapy school (i.e., named "X") in partnership with Paris-Saclay University. About 450 students are enrolled in "X" four-year physiotherapy study program. Every year, approximately 100 first-year students are admitted to "X" for the first common year of health education.

2.3. Participants

We considered data from second- and third-year physiotherapy students. This study was conducted over three university years from September 2017 to July 2020. Repeat students and students with flexible work arrangements (i.e., top-level athletes) were excluded. The study complied with the standards set by the Declaration of Helsinki (34). All participants gave written informed consent after being instructed as to the nature and purpose of the study, which was approved by the local ethics committee of Paris-Saclay University under registration number CER-Paris-Saclay-2020-095.

A baseline group (2017–18 baseline group) was formed of second-year physiotherapy students who attended only in-person gross anatomy courses with no specific physiotherapy musculoskeletal blended learning in anatomy (from September 2017 to July 2018).

Two experimental groups (2018–19 and 2019–20 experimental groups) were formed. Both groups had previously attended in-person gross anatomy courses and specific physiotherapy musculoskeletal anatomy blended learning (from September 2018 to July 2019, and from September 2019 to July 2020).

2.4. Intervention

Thirty-two musculoskeletal anatomy blended learning units were created for the second year of physiotherapy studies at "X." The learning objectives were to focus on musculoskeletal anatomy to complement the gross anatomy studies delivered at Paris-Saclay University. These studies were dedicated to myology, osteology and arthrology of the upper and lower limbs. To standardize and homogenize the content of these blended learning units, all were prepared and recorded by the same individual (Professor of musculoskeletal anatomy, with 10 years of teaching experience). None of the students received direct in-person instruction from this individual. The 32 blended learning units were peer reviewed by the authors of this article for consistency and quality of content. All blended learning units were broadcast by the intranet server of "X" physiotherapy school (i.e., digital teaching platform accessible at http://www.learneos.fr) and freely accessible for each student on their own school's account.

To control bias, all of the blended learning units had the same structure and duration (i.e., 30 min) and were pre-recorded with the same teacher's voice. The blended learning units were composed of anatomy bullet text, 2D/3D musculoskeletal anatomy pictures (i.e., illustrations, diagrams and 3D models) and cadaveric musculoskeletal images. No e-video was included in the blended learning units.

2.5. Variables

2.5.1. Primary outcome

The anatomy skills developed by the students were assessed through first- and second-semester final examination results. We compared the results of students with traditional face-to-face learning (2017–18 baseline group) with those of students having completed the blended learning program (2018–19 and 2019–20 experimental groups). Success in the anatomy teaching unit was defined by the rules of the physiotherapy program: students were required to obtain a score of 10 out of 20 (or 50%) on the first multiple-choice exam. Multiple-choice exam is composed of 30 to 40 multiple-choice questions (i.e., 4 possible answers for each question) based on musculoskeletal anatomy program of the first-year physiotherapy students (i.e., myology, osteology and arthrology of the upper and lower limbs).

2.5.2. Secondary outcomes

An investigation field was made through an online data survey to evaluate the pedagogical value of musculoskeletal blended learning and its usefulness for preparing the student for their anatomy final written exam at "X" physiotherapy school.

The retrospective target and eligible population and the eligibility criteria corresponded to second- to third-year physiotherapy students at "X" physiotherapy school over three university years from September 2017 to July 2020.

Concerning the sources and methods of selection, all the participants were recruited through the survey. Participants were able to complete the survey at any time during the period mentioned above. All data were self-reported by the participants. The survey was anonymous, and data confidentiality was assured in accordance with the European General Data Protection Regulation.

The 2018–19 and 2019–20 experimental group students were asked to evaluate the pedagogical value and interest of blended learning as an effective tool for preparing written semester exams (Table 1).

2.6. Bias

Considering our study design, several potential biases must be underlined. First, we cannot exclude a social desirability bias (where respondents to surveys tend to answer in a manner they feel will be seen as favorable by others) and a selection bias given the way we recruited participants through monocentric training institute.

2.7. Statistical methods

A descriptive analysis was performed to determine the average score of each blended learning unit. The Shapiro–Wilk W test was used to evaluate each variable for normality and established that nonparametric statistic tests should be used (Shapiro test with $p < 0.001$). The mean score during both semesters concerned was compared for 2017–18 and 2019–20 with Kruskal-Wallis test. The mean score between groups (i.e., 2017–18 baseline group, 2018–19 and 2019–20 experimental groups) was compared with Mann–Whitney test. Statistical analysis was performed using JASP® (Version 0.14.1, Amsterdam, Netherlands). A Fisher's exact test was performed to determine the association between dependent and independent variables. Statistical analysis was performed using SPSS statistical software (Version 23.0 for Mac, SPSS, Inc., Chicago, IL). The level of significance was established at $p < 0.05$.

3. Results

3.1. Participants and descriptive data

A total of 308 students were included in the three cohorts, with 23 students being excluded due to academic repetition or having flexible work arrangements (Figure 2).

We considered ninety-two first-year students (19 ± 1 years old; 52 males and 39 females) in the 2017–18 baseline group, and ninety-eight first-year students (20 ± 1 years old; 49 males and 49 females) and ninety-five second-year students (21 ± 2 years old; 52 males and 43 females) in the 2018–19 and 2019–20 experimental groups.

3.2. Main results

3.2.1. Primary outcome

For the main outcome, we observed an improvement in the success rate of the anatomy final written exam between the 2017–18 baseline group and the 2018–19 and 2019–2020 experimental groups. Success rate is defined by the percentage of students scoring 50% or above. Table 2 shows an improved success rate of the anatomy final written exam for both semesters studied.

TABLE 1 2018–19 and 2019–20 experimental group student's questionnaire assessment.

Assessment items	Questionnaire assessment
Pedagogical value of musculoskeletal anatomy e-learning	Question 1. Did you find blended learning support useful in learning musculoskeletal anatomy? Only one answer possible: ☐ Yes ☐ No
	Question 2. Could blended learning replace in-person classroom lectures? Only one answer possible: ☐ Yes ☐ No
	Question 3. For the next cohort of second-year physiotherapy students, should in-person anatomy classes be maintained in addition to blended learning? Only one answer possible: ☐ Yes ☐ No
	Question 4. Would you like to receive anatomy musculoskeletal e-video learning resources? Only one answer possible: ☐ Yes ☐ No
	Question 5. For you, is it "essential" to include cadaveric musculoskeletal images in blended learning? Only one answer possible: ☐ Yes ☐ No
	Question 6. For you, is it "essential" to practice "cadaveric dissection" during physiotherapy studies at "X"? Only one answer possible: ☐ Yes ☐ No
Usefulness of musculoskeletal anatomy e-learning for preparing for the final written exam	Question 7. Was blended learning useful for preparing for the final written exam? Only one answer possible: ☐ Yes ☐ No
	Question 8. Was blended learning useful in preparing for your future profession as a physiotherapist? Only one answer possible: ☐ Yes ☐ No
	Question 9. Do you believe that blended learning allowed you to learn musculoskeletal anatomy more easily than in-person learning at Paris-Saclay University's Faculty of Medicine? Only one answer possible: ☐ Yes ☐ No
	Question 10†. For the next cohort of second-year physiotherapy students, do you believe it essential to maintain anatomy classes with in-person teaching in addition to blended learning? Only one answer possible: ☐ Yes ☐ No

†Assessment specific to 2019–20 (3rd year) experimental group.

For the first semester, the mean score results to final exam of the 2017–18 baseline group, and of the 2018–19 and 2019–20 experimental groups improved (Kruskal-Wallis = 74.06, df = 2, value of $p<0.001$) (Table 3 and Figure 3).

For the second semester, the mean score results to final exam of the 2017–18 baseline group, and of the 2018–19 and 2019–20 experimental groups improved (Kruskal-Wallis = 173.6, df = 2, value of $p<0.001$) (Table 3 and Figure 3).

The mean score results to final exam of 2018–19 experimental group significantly decreased (Mann–Whitney = 6195.5, value of $p<0.001$) compared to the 2017–18 baseline group.

The mean score results to final exam of 2019–20 experimental group significantly increased (Mann–Whitney = 163.0, value of $p<0.001$) compared to 2018–19 experimental groups.

3.2.2. Secondary outcomes

For the secondary outcome, we analyzed the pedagogical value and usefulness of for musculoskeletal blended learning for preparing for the "X" final written exam. We obtained a data survey and questionnaire response rate (Figure 3; in line with 2018–19 and 2019–20 experimental group students questionnaire assessment of Table 1) of 74.2% (total of 89/120 data surveys and responses available) for the 2018–19 experimental group, and 62.1% (total of 72/116 data surveys and responses available) for the 2019–20 experimental group. Concerning questionnaire response, they were no significant statistical difference between 2018–19 and 2019–20 experimental group students.

3.2.2.1. Pedagogical value

We observed that 74% ($n = 66/89$) of 2018–19 experimental group students and 80% ($n = 58/72$) of 2019–20 experimental group students said that blended learning could not replace in-person classroom lectures (see Q1 of Figure 4).

However, 64% (n = 57/89) of 2018–19 experimental group students and 58% (n = 42/72) of 2019–20 experimental group students found that blended learning support is useful for learning musculoskeletal anatomy (see Q2 of Figure 4).

3.2.2.2. Usefulness of blended learning for preparing for final exam

The assessment of musculoskeletal blended learning as an efficient tool for preparing for the "X" final written exam showed that 61% (n = 54/89) of 2018–19 experimental group students and 60% ($n = 43/72$) of 2019–20 experimental group students do not consider blended learning anatomy to be useful in preparing for the final written exam (see Q7 of Figure 4).

4. Discussion

4.1. Key results

The primary outcome showed a significant improvement in the success rate of the anatomy final written exam for both semesters studied in the 2018–19 and 2019–20 experimental groups compared

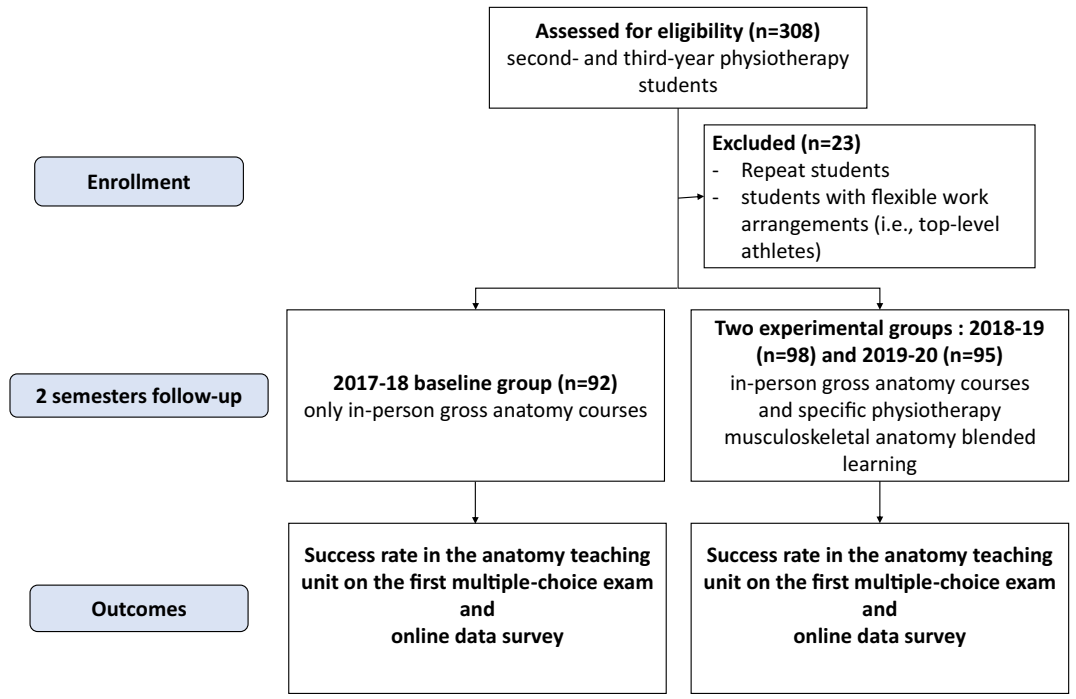


FIGURE 2
Flowchart of the study.

TABLE 2 Success rate of the anatomy final written exam for both semesters studied of the 2017–18 baseline group, and of the 2018–19 and 2019–20 experimental groups.

	First semester				Second semester			
Year	n	n Success 1st exam	n Success 2nd exam	Success rate[¥] (%)	n	n Success 1st exam	n Success 2nd exam	Success rate[¥] (%)
2017–18	92	45	37	89	98	55	13	69
2018–19	98	84	12	98	99	38	43	82
2019–20	95	84	11	100	96	96	n/a	100

n, number of students.[¥]Success rate is defined by the percentage of students scoring 50% or above.

to the 2017–18 baseline group. Mean score results for the final exam were significantly better in the experimental groups than in the baseline group. The secondary outcomes explored the pedagogical value and usefulness of musculoskeletal blended learning for preparing for the anatomy final written exam. A majority of students found blended learning helpful for learning musculoskeletal anatomy, although they believed it could not fully replace in-person classroom lectures for anatomy instruction. Overall, the study suggests that implementing blended learning can lead to improved exam performance and is considered valuable for learning musculoskeletal anatomy by many students, though not as a complete substitute for traditional classroom lectures.

In physiotherapy education, the use of blended learning increases: knowledge, practical skills acquisition (19, 21), satisfaction/attitude in physiotherapy students (20) and workload (22). In line of the literature, the primary outcome of the study suggests that the addition of e-learning to traditional learning improved the success rate of physiotherapy students in gross anatomy. This improvement may be attributed to the better organization of students facilitated by the creation of a note-taking network specific to the e-learning course. In other words, the implementation of e-learning resources and tools had a positive impact on students' ability to organize and comprehend the subject matter, leading to improved academic performance. On the other hand, the secondary outcome reveals that despite the positive effects observed in the primary outcome, the majority of students did not consider e-learning anatomy useful in preparing for the final written exam. They expressed a belief that in-person classroom lectures were irreplaceable when it came to studying anatomy. Several factors may contribute to the differences between the primary and secondary outcomes. Firstly, Learning Preferences: Students have diverse learning preferences and styles. While some may find e-learning resources effective for organizing and understanding the material, others may prefer the traditional classroom setting and face-to-face interactions for learning complex subjects like anatomy (35, 36). The secondary outcome highlights the continued preference for in-person lectures among some students. Secondly, Perceived Value: Students' perceptions of the value and relevance of e-learning resources may vary (37). Even though the primary outcome suggests improved success rates, students may not perceive the e-learning anatomy resources as directly contributing to their performance in the

TABLE 3 Results of final exam of the 2017–18 baseline group, and of the 2018–19 and 2019–20 experimental groups. n: number of students.

		First semester			Second semester			
Year	n	Mean result*	Median (IQR)	*p*-value Kruskal–Wallis test	n	Mean result*	Median (IQR)	*p*-value Kruskal–Wallis test
2017–18	92	9.87	9.91 (2.47)	Kruskal-Wallis = 74.06, df = 2, value of $p<0.001$	102	10.19	10.54 (5.03)	Kruskal–Wallis = 173.6, df = 2, value of $p<0.001$
2018–19	98	11.70	12.19 (2.02)		99	8.96	8.82 (4.06)	
2019–20	95	12.29	12.58 (1.77)		96	15.77	16.14 (2.09)	

IQR, interquartile range.*Min: 0; Max: 20.

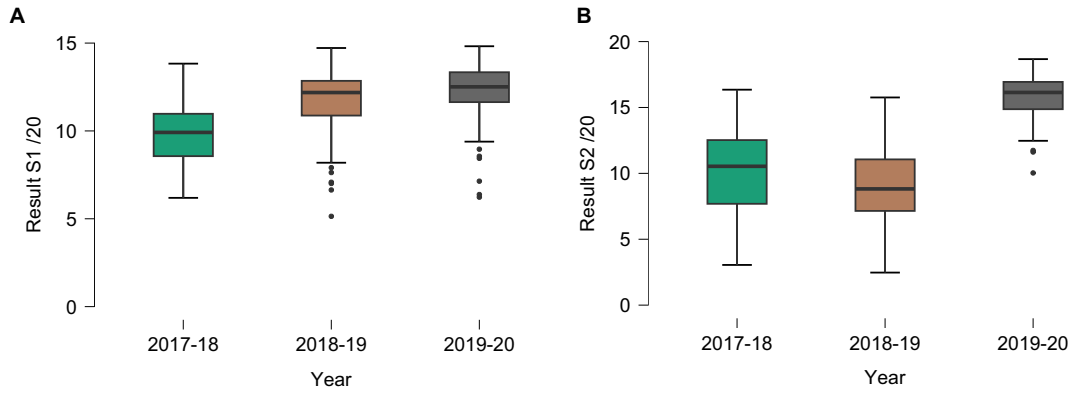


FIGURE 3
Mean result and standard deviation of students for first **(A)** and second **(B)** semesters in anatomy without (2017–18 baseline group) and with blended learning (2018–19 and 2019–20 experimental groups). S1: first semester; S2: second semester.

final exam. They may prioritize the interactive nature, real-time feedback, and immediate clarification opportunities provided by in-person lectures. Thirdly, Comfort and Familiarity: Students may be more comfortable and familiar with traditional classroom lectures due to their prior educational experiences. They might have developed effective study strategies and routines around in-person lectures, making it difficult for them to fully embrace and utilize the e-learning resources for exam preparation (38). Finally, this difference car be explained by Subject Complexity: Anatomy is a complex subject that often requires hands-on learning, visual aids, and direct interaction. Some students may perceive e-learning resources as inadequate in providing these elements, which can lead to their preference for in-person classroom lectures (39). It is important to note that these differences in perception and preference between the primary and secondary outcomes do not negate the positive impact of e-learning observed in the primary outcome. Instead, they highlight the need for considering individual learning styles and preferences when implementing blended learning approaches and designing effective e-learning resources for anatomy education (40, 41).

4.2. Limitations

The limitations of this retrospective study are the risk of memory bias for 2019–20 experimental student's group and the absence of a musculoskeletal anatomy e-learning performance assessment such as the one conducted by Laveneziana et al. (42). However, it is the first pedagogical study assessment performed in a French physiotherapy school. Pedagogical management needs to be studied further scientifically, especially because of the recent creation of the National University Council ("CNU 91") for Reeducation and Rehabilitation Sciences approved by the French Ministry. Moreover, this questionnaire has been translated to English and the lack of piloting, forward and backward translation is a severe limitation. The methodology used for the questionnaire could be notably enhance by using the Likert scale for example. The questionnaire was more related to a field investigation. The reliability and validity were not tested. Further studies need to take into account some confusing factor with a stratified analysis (e.g., the level of exam difficulty, the level of the students, the used of incidental/parallel learning of anatomy other than the e-learning resource, the individual duration time according to learn during the pandemic, …)".

4.3. Interpretations

4.3.1. About the overall education process

As previously described by Freeman et al. (43), the results of this study show that e-learning added to traditional learning of gross anatomy (i.e., blended learning) could improve the success rate of physiotherapy students. It seems that the student's anatomy results are optimal two years after the introduction of e-learning in physiotherapy school. It is probably linked to a better organization of physiotherapy students thanks to the creation of note-taking network specific to the e-learning course, which benefited the students from the following group (see results of group 2019–20 on Figure 2).Our results confirm

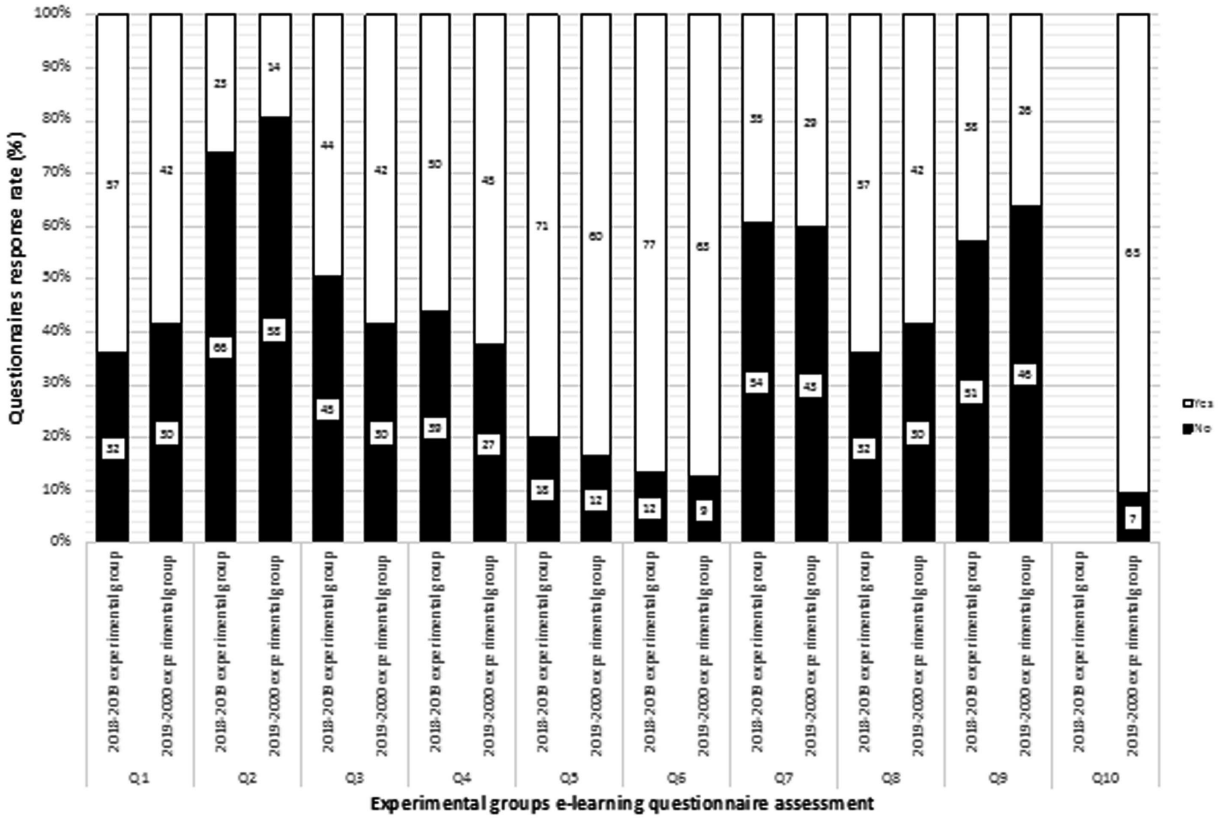


FIGURE 4
Comparison of 2018–19 (n = 89) and 2019–20 (n = 72) students questionnaire response rate. Q: question in line with Table 1. The number of each respondent (i.e., "yes" and "no") is indicated on each column from Q1 to Q10.

that anatomy e-learning cannot replace in-person classroom lectures, although the majority of students consider it a useful teaching format for anatomy (44). The new findings of this study are as follows: (1) the majority of students do not consider e-learning anatomy useful in preparing for the final written exam and would like to have anatomy video e-learning as a complement. In fact, the use of video e-learning support at the beginning of the first semester could help health students to improve their university exam performance (42). A recent systematic review, written by Noetel et al. (45), underlines that videos are unlikely to be detrimental and usually improve student learning at university. A recent meta-analysis, conducted by Fontaine et al. (46) also suggests that adaptive e-learning (notably with videos) appear effective in improving skills in health students and professionals by generating less cognitive load.

4.3.2. Unexpected results

However, it should be noted that the decrease in mean score results for the final exam of the 2018–19 experimental group, compared to both the 2017–18 baseline group and the 2019–20 experimental group, raises interesting questions. Several potential factors may explain these results, particularly within the 2018–19 experimental group. One possible explanation could be a lack of organizational strength and insufficient sleep among the students, with reported sleep durations as short as 3–4 h per night (47). Such sleep deprivation has been linked to cognitive impairment and decreased academic performance. Additionally, it's important to consider the overall performance of the student cohort during that period. It is plausible that the 2018–19 group, as a whole, experienced lower academic performance compared to other cohorts. This could be attributed to various factors, such as changes in the curriculum, teaching methods, or even external influences like personal circumstances or distractions. Nonetheless, it is crucial to acknowledge that our study did not assess the quality of students' lives during the research period. Research has shown that factors like lifestyle, stress levels, and overall well-being can significantly impact the academic performance of health students (48). Therefore, it is possible that the observed decline in exam scores could be related to such unmeasured variables. Future studies should consider exploring the influence of these factors to gain a comprehensive understanding of the performance variations observed among different student groups. That is why while the decrease in mean scores for the 2018–19 experimental group is evident, it is essential to recognize the limitations of our study and the potential influence of various factors on academic performance. Further investigation considering factors like sleep patterns, overall well-being, and students' quality of life would provide valuable insights into the observed outcomes.

4.3.3. About student's satisfaction

The overall quality of e-learning was good based on the ratings assigned by the majority of students. E-learning is of professional value for physiotherapy students as it can improve their ability to anticipate clinical situations and physiotherapy tasks. Mazzoleni et al.

(49) showed that students (72% of 2034 users) are generally satisfied with the blended learning content and that it contributes to the improvement of results in continuing medical education. For corroborate this result, Jebraeily et al. (50) have reported, through a recent qualitative study, that the productive lecturer-student interactions were improved with the virtual component, students yet questioned the lack of sufficient and on-time feedback from the lecturers on their activities. They suggest that the use of different types of interactions should still be monitored and promoted through online discussions, on-time feedbacks, and forums to compensate for the lack of rich face-to-face interactions that take place for clarifications or confirmations in classroom teaching. The authors propose a systematic evaluation of blended medical education from lecturers and student's viewpoint using the following items: Strengths, Weaknesses, Opportunities, and Threats (SWOT). In a pedagogical way, they propose the analysis of SWOT items and it mindful consideration in each context, in order to adopt the right implementation and management strategies to achieve sustainable benefits for students and pedagogical team.

Students consider the presence of *in-vivo* anatomical dissection pictures to be indispensable in the e-learning support and describe anatomical dissection as fundamental during physiotherapy studies. The study found that the adoption of blended learning in physiotherapy education assisted physiotherapy students to perform better in exams and develop relevant skills. It is suggested that the use of video e-learning support at the beginning of the first semester could help healthy students to improve their university exam performance.

4.3.4. Educational considerations

From a pedagogical point of view, similar results were highlighted who stressed the need to combine e-learning with in-person courses (i.e., blended learning) to limit the risk of students "dropping out" [Varga-Atkins et al., 2005; (26, 27)].

In our observation, the majority of the 2018–19 and 2019–20 experimental student's groups [i.e., 2018–19 experimental group students: 74.2% (n = 72) and 2019–20 experimental student's groups: 80.6% (n = 76)] do not believe that e-learning anatomy will replace in-class anatomical courses in the future. This corroborates the results of Ruiz et al. (32) who point out that students do not see e-learning as a replacement for traditional classroom training, but as complementing it.

E-learning is a professional value for physiotherapy students. For example, it is demonstrated that e-learning improves the ability to anticipate clinical situations and physiotherapy tasks (51). Our findings corroborate the results of Riffell & Merrill (52) supporting the fact that e-learning must be included in the educational program right from the beginning of the university program. This encouraged the «X» anatomy teaching team to add e-learning to first-year physiotherapy studies.

Therefore, the «X» anatomy teaching team will maintain this teaching format with 2018–19 experimental student's groups. The results of a meta-analysis (53) comparing an online versus in-person learning situation showed that students with online learning achieved better results than those receiving in-person instruction. However, students who received combined learning (i.e., online and in-person) achieved the best results. Our results corroborate this observation, with 90.3% (n = 85) of 2019–20 experimental student's groups considering it essential to maintain anatomy classes with in-person teaching at «X» in addition to anatomy e-learning for the next cohort of 2018–19 experimental student's groups.

Laveneziana et al. (42) showed that 50% of second-year medical students believe that e-learning video sessions could replace the traditional classroom (i.e., in-person). This result is also found in the literature (54–56). Actually, most of pedagogical teams (e.g., physiotherapy and medicine), work with e-video-based lectures, coupled to peer-mentoring (57), for enhancing the anatomy skills (58–60) of students and their diagnosis (54, 55).

These observations remain to be qualified since 74.2% (n = 72) of 2018–19 experimental student's groups and 80.6% (n = 76) of 2019–20 experimental student's groups think that e-learning cannot replace traditional classroom courses. This can be explained by the fact that, pedagogically, physiotherapy students are required to develop their anatomical knowledge better in a sensitivo-sensory practical aspect (i.e., touching, massaging, manipulating, observing anatomical structures) compared to second-year students of medicine (61).

Indeed, physiotherapy students' use up to six palpatory skills (62) integrated in a somato-psychic educational process (63). The use of e-video would also improve test preparation (56, 64) and optimize students' learning pattern (54, 65). Guy et al. (57) showed that students using e-video media available in their curriculum in addition to their traditional course materials achieved better results, and there was a linear relationship between the number of e-video viewed by the students and their results on the exams.

Physiotherapy students (2018–19 and 2019–20 experimental student's groups) assign particular importance to anatomical dissection and dissection pictures as a teaching aid. This corroborates the meta-analysis conducted by Yammine and Violato (66) where the use of physical models was shown to provide statistically superior results in short- and long-term overall anatomical knowledge acquisition and spatial tracking, compared to 3D modeling alone. The use of 2D and 3D interactive anatomical support allows students, regardless of their spatial anatomical modeling ability (67), to progress in learning anatomy (68), including by combining these two supports (69). However, a literature review conducted by (70) shows that the use of 3D anatomical support versus traditional teaching is equal. Therefore, for physiotherapy students, anatomy blended learning must present cadaveric musculoskeletal images paired with dissection in the laboratory. These results are in line with the literature (71) which considered cadaveric dissection as an educational tool for anatomical sciences improving teamwork, self-reflection, interprofessional communication skills, and ethical qualities. Varying the modes of anatomical learning would optimize visuo-constructive capabilities and visual–spatial anatomical identification, as is the case in surgery (72).

4.4. Generalisability

The results of this study need to be reinforced by a multinational study. We can also mention the epistemological limitations inherent in the quantitative approach of this type of study (observational survey study). Indeed, purely quantitative approaches restrict the field of analysis and do not allow for an in-depth understanding of the behavior of individuals. The complementary use of qualitative approaches, allowing a broader, more complete, more global, and richer understanding of the phenomena studied, is to be sought.

The need to enhance anatomy education in physiotherapy schools was brought into focus by the global COVID-19 pandemic (73) thanks to a multidisciplinary approach (74). Further studies are required to better understand the pedagogical needs of anatomy educators and physiotherapy students in order to improve professional skills.

5. Conclusion

Blended learning, which combines e-learning with traditional in-person teaching, can improve the success rate of physiotherapy students, particularly in gross anatomy. The optimal results are observed two years after the introduction of e-learning, which may be due to the better organization of students thanks to the creation of note-taking networks specific to the e-learning course. However, e-learning cannot replace in-person classroom lectures, although the majority of students consider it a useful teaching format for anatomy. Most students believe that e-learning anatomy cannot replace in-class anatomical courses in the future, but it can complement them. The study also shows that the presence of *in-vivo* anatomical dissection pictures is indispensable in the e-learning support, and e-learning improves the ability to anticipate clinical situations and physiotherapy tasks. Furthermore, the students who received combined learning (i.e., online and in-person) achieved the best results. Therefore, the "X" physiotherapy school anatomy teaching team will maintain the blended learning format with in-person teaching at "X" in addition to anatomy e-learning for the next cohort.

In conclusion, since recent years, teaching in physiotherapy is undergoing a substantial change by the use of new teaching methods (75). Digital and massive online courses need a strong cooperation between political, scientific and professional actors (8). In this global educational context, blended teaching should be integrated into physiotherapy in the future and tested by combining/mixing teaching techniques for manual skills as well as theoretical knowledge (76–79). Also, specific outcomes (e.g., psychological, emotional) and the ability to use digital technology to self-learn and teach others must be consider for future studies (29).

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by the Ethics Committee of Paris-Saclay University under registration number CER-Paris-Saclay-2020-095. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements.

Author contributions

AD: Conceptualization, Data curation, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft. GS: Conceptualization, Validation, Visualization, Writing – original draft. JF: Conceptualization, Investigation, Validation, Writing – original draft. LF: Conceptualization, Validation, Writing – original draft. OD: Conceptualization, Data curation, Methodology, Validation, Writing – original draft. F-RS: Conceptualization, Data curation, Formal analysis, Methodology, Validation, Writing – original draft.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Remondière R, Durafourg MP. A new look at physiotherapy in France in 2018. *Sante Publique*. (2018) 30:869–76. doi: 10.3917/spub.187.0869

2. Sarhan FR, Lecocq F. Réforme de la formation: quels impacts pour l'exercice salarié? *Kinésithér Rev*. (2015) 15:69–71. doi: 10.1016/j.kine.2015.09.037

3. Pérez-Roux T. *La réforme des études en santé: entre universitarisation et professionnalisation. Le cas des Instituts de Formation en Masso-Kinésithérapie. 1st* ed. Paris, FR: L'Harmattan, Éducation et socialisation (2019).

4. Segouin C, Jouquan J, Hodges B, Bréchat P-H, David S, Maillard D, et al. Country report: medical education in France. *Med Educ*. (2007) 41:295–301. doi: 10.1111/j.1365-2929.2007.02690.x

5. Maleyrot É, Perez-Roux T, Pourcelot C, Hébrard P. Comprendre le travail de mise en œuvre de la réforme des études en Masso-Kinésithérapie (2015): le cas d'un institut de formation. *Activités*. (2019) 16:1–26. doi: 10.4000/activites.3853

6. Michon D. Tenir la dialogique « intégration universitaire et amélioration continue de la professionnalisation ». *Kinésithér Rev*. (2020) 20:1–2. doi: 10.1016/j.kine.2020.09.001

7. Longhini J, De Colle B, Rossettini G, Palese A. What knowledge is available on massive open online courses in nursing and academic healthcare sciences education? A rapid review. *Nurse Educ Today*. (2021a) 99:104812. doi: 10.1016/j.nedt.2021.104812

8. Longhini J, Rossettini G, Palese A. Massive open online courses for nurses' and healthcare professionals' continuous education: a scoping review. *Int Nurs Rev*. (2021b) 68:108–21. doi: 10.1111/inr.12649

9. Rossettini G, Geri T, Turolla A, Viceconti A, Scumà C, Mirandola M, et al. Online teaching in physiotherapy education during COVID-19 pandemic in Italy: a retrospective case-control study on students' satisfaction and performance. *BMC Med Educ*. (2021a) 21:456. doi: 10.1186/s12909-021-02896-1

10. Rossettini G, Turolla A, Gudjonsdottir B, Kapreli E, Salchinger B, Verheyden G, et al. Digital entry-level education in physiotherapy: a commentary to inform post-COVID-19 future directions. *Med Sci Educ*. (2021b) 31:2071–83. doi: 10.1007/s40670-021-01439-z

11. Shead DA, Roos R, Olivier B, Ihunwo AO. Curricular and pedagogical aspects of gross anatomy education for undergraduate physiotherapy students: a scoping review. *JBI Evid Synth*. (2020) 18:893–951. doi: 10.11124/JBISRIR-2017-003903

12. García-González J, Ruqiong W, Alarcon-Rodriguez R, Requena-Mullor M, Ding C, Ventura-Miranda MI. Analysis of anxiety levels of nursing students because of e-learning during the COVID-19 pandemic. *Healthcare (Basel)*. (2021) 9:252. doi: 10.3390/healthcare9030252

13. George PP, Papachristou N, Belisario JM, Wang W, Wark PA, Cotic Z, et al. Online eLearning for undergraduates in health professions: a systematic review of the impact on knowledge, skills, attitudes and satisfaction. *J Glob Health*. (2014) 4:010406. doi: 10.7189/jogh.04.010406

14. Ng L, Seow KC, MacDonald L, Correia C, Reubenson A, Gardner P, et al. eLearning in physical therapy: lessons learned from transitioning a professional education program to full elearning during the COVID-19 pandemic. *Phys Ther*. (2021) 101. doi: 10.1093/ptj/pzab082

15. Sarfaraz S, Ahmed N, Abbasi MS, Sajjad B, Vohra F, Al-Hamdan RS, et al. Self-perceived competency of the medical faculty for e-teaching during the COVID-19 pandemic. *Work*. (2020) 67:791–8. doi: 10.3233/WOR-203332

16. Swaminathan N, Govindharaj P, Jagadeesh NS, Ravichandran L. Evaluating the effectiveness of an online faculty development programme for nurse educators about remote teaching during COVID-19. *J Taibah Univ Med Sci*. (2021) 16:268–73. doi: 10.1016/j.jtumed.2020.11.003

17. Dario A, Simic M. Innovative physiotherapy clinical education in response to the COVID-19 pandemic with a clinical research placement model. *J Physiother*. (2021) 67:235–7. doi: 10.1016/j.jphys.2021.08.008

18. Etoom M, Aldaher KN, Abdelhaq AA, Alawneh A, Alghwiri AA. Predictors of distance learning in physiotherapy students during COVID-19 outbreak. *Physiother Theory Pract*. (2022) 39:1513–8. doi: 10.1080/09593985.2022.2042438

19. Ødegaard NB, Myrhaug HT, Dahl-Michelsen T, Røe Y. Digital learning designs in physiotherapy education: a systematic review and meta-analysis. *BMC Med Educ*. (2021) 21:48. doi: 10.1186/s12909-020-02483-w

20. Shahali S, Shahabi S, Kohan N, Ebrahimi I, Ebrahimi R. Using e-learning methods for physiotherapy students learning – a systematic review and meta-analysis of the impact on knowledge, skills, satisfaction and attitudes. *Eur J Phys*. (2022) 13:789. doi: 10.1080/21679169.2022.2085789

21. Vallée A, Blacher J, Cariou A, Sorbets E. Blended learning compared to traditional learning in medical education: systematic review and meta-analysis. *J Med Internet Res*. (2020) 22:e16504. doi: 10.2196/16504

22. Ravat S, Barnard-Ashton P, Keller MM. Blended teaching versus traditional teaching for undergraduate physiotherapy students at the University of the Witwatersrand. *S Afr J Physiother*. (2021) 77:1544. doi: 10.4102/sajp.v77i1.1544

23. Wutoh R, Boren SA, Balas AE. eLearning: a review of internet-based continuing medical education. *JCEHP*. (2004) 24:20–30. doi: 10.1002/chp.1340240105

24. Varga-Atkins T, Cooper H. Developing e-learning for interprofessional education. *J Telemed Telecare*. (2005) 11:102–4. doi: 10.1258/1357633054461561

25. Jowsey T, Foster G, Cooper-Ioelu P, Jacobs S. Blended learning via distance in pre-registration nursing education: a scoping review. *Nurse Educ Pract*. (2020) 44:102775. doi: 10.1016/j.nepr.2020.102775

26. Liu Q, Peng W, Zhang F, Hu R, Li Y, Yan W. The effectiveness of blended learning in health professions: systematic review and meta-analysis. *J Med Internet Res*. (2016) 18:e2. doi: 10.2196/jmir.4807

27. Zinkernagel A, Alexandrowicz RW, Lischetzke T, Schmitt M. The blenderFace method: video-based measurement of raw movement data during facial expressions of emotion using open-source software. *Behav Res*. (2019) 51:747–68. doi: 10.3758/s13428-018-1085-9

28. O'Byrne PJ, Patry A, Carnegie JA. The development of interactive online learning tools for the study of anatomy. *Med Teach*. (2008) 30:e260–71. doi: 10.1080/01421590802232818

29. Longhini J, Rossettini G, Palese A. Digital health competencies among health care professionals: systematic review. *J Med Internet Res*. (2022) 24:e36414. doi: 10.2196/36414

30. Green RA, Whitburn LY. Impact of introduction of blended learning in gross anatomy on student outcomes. *Anat Sci Educ*. (2016) 9:422–30. doi: 10.1002/ase.1602

31. O'Doherty D, Dromey M, Lougheed J, Hannigan A, Last J, McGrath D. Barriers and solutions to online learning in medical education - an integrative review. *BMC Med Educ*. (2018) 18:130. doi: 10.1186/s12909-018-1240-0

32. Ruiz JG, Mintzer MJ, Leipzig RM. The impact of E-learning in medical education. *Acad Med*. (2006) 81:207–12. doi: 10.1097/00001888-200603000-00002

33. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, et al. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol*. (2008) 61:344–9. doi: 10.1016/j.jclinepi.2007.11.008

34. World Medical Association. World medical association declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA*. (2013) 310:2191–4. doi: 10.1001/jama.2013.281053

35. Abdullah E, Lone M, Cray JJ, Dvoracek P, Balta JY. Medical Students' opinions of anatomy teaching resources and their role in achieving learning outcomes. *Med Sci Educ*. (2021) 31:1903–10. doi: 10.1007/s40670-021-01436-2

36. Acosta ML, Sisley A, Ross J, Brailsford I, Bhargava A, Jacobs R, et al. Student acceptance of e-learning methods in the laboratory class in optometry. *PLoS One*. (2018) 13:e0209004. doi: 10.1371/journal.pone.0209004

37. Alomar AZ. Undergraduate medical Students' perceptions of an online audio-visual-based module for teaching musculoskeletal physical examination skills. *J Med Educ Curric Dev*. (2022) 9:1078794. doi: 10.1177/23821205221078794

38. Agha S, Alhamrani AY, Khan MA. Satisfaction of medical students with simulation based learning. *Saudi Med J*. (2015) 36:731–6. doi: 10.15537/smj.2015.6.11501

39. Böckers A, Jerg-Bretzke L, Lamp C, Brinkmann A, Traue HC, Böckers TM. The gross anatomy course: an analysis of its importance. *Anat Sci Educ*. (2010) 3:11. doi: 10.1002/ase.124

40. Gardner P, Slater H, Jordan JE, Fary RE, Chua J, Briggs AM. Physiotherapy students' perspectives of online e-learning for interdisciplinary management of chronic health conditions: a qualitative study. *BMC Med Educ*. (2016) 16:62. doi: 10.1186/s12909-016-0593-5

41. Olivier B, Verdonck M, Caseleijn D. Digital technologies in undergraduate and postgraduate education in occupational therapy and physiotherapy: a scoping review. *JBI Evid Synth*. (2020) 18:863–92. doi: 10.11124/JBISRIR-D-19-00210

42. Laveneziana P, Duguet A, Straus C. How can video-based sessions improve e-learning of respiratory physiology? *Arch Bronconeumol*. (2017) 53:477–9. doi: 10.1016/j.arbres.2017.03.002

43. Freeman S, Eddy SL, McDonough M, Smith MK, Okoroafor N, Jordt H, et al. Active learning increases student performance in science, engineering, and mathematics. *Proc Natl Acad Sci USA*. (2014) 111:8410–5. doi: 10.1073/pnas.1319030111

44. Vaona A, Banzi R, Kwag KH, Rigon G, Cereda D, Pecoraro V, et al. E-learning for health professionals. *Cochrane Database Syst Rev*. (2018) 2018:CD011736. doi: 10.1002/14651858.CD011736.pub2

45. Noetel M, Griffith S, Delaney O, Sanders T, Parker P, del Pozo CB, et al. Video improves learning in higher education: a systematic review. *Rev Educ Res*. (2021) 91:204–36. doi: 10.3102/0034654321990713

46. Fontaine G, Cossette S, Maheu-Cadotte M-A, Mailhot T, Deschênes M-F, Mathieu-Dupuis G, et al. Efficacy of adaptive e-learning for health professionals and students: a systematic review and meta-analysis. *BMJ Open*. (2019) 9:e025252. doi: 10.1136/bmjopen-2018-025252

47. DeVilbiss C, Rice VJ, Laws L, Alfred P. If you want to know why students fail, just ask them. *US Army Med Dep J*. (2010) 9:e025252.

48. Chattu VK, Sahu PK, Seedial N, Seecharan G, Seepersad A, Sieunarine M, et al. An exploratory study of quality of life and its relationship with academic performance among students in medical and other health professions. *Med Sci (Basel)*. (2020) 8:23. doi: 10.3390/medsci8020023

49. Mazzoleni MC, Rognoni C, Finozzi E, Giorgi I, Pugliese F, Landro M, et al. Usage and effectiveness of e-learning courses for continuous medical education. *Stud Health Technol Inform*. (2009) 150:921–5. doi: 10.3233/978-1-60750-044-5-921

50. Jebraeily M, Pirnejad H, Feizi A, Niazkhani Z. Evaluation of blended medical education from lecturers' and students' viewpoint: a qualitative study in a developing country. *BMC Med Educ*. (2020) 20:482. doi: 10.1186/s12909-020-02388-8

51. Major ME, Ramaekers SPJ, Engelbert RHH, Van der Schaaf M. Preparing undergraduate students for clinical work in a complex environment: evaluation of an e-learning module on physiotherapy in the intensive care unit. *BMC Med Educ*. (2020) 20:130. doi: 10.1186/s12909-020-02035-2

52. Riffell S, Merrill J. Do hybrid lecture formats influence laboratory performance in large, pre-professional biology courses? *JNRLSE*. (2005) 34:96–100. doi: 10.2134/jnrlse.2005.0096

53. Means B, Toyama Y, Murphy R, Bakia M, Jones K. Evaluation of evidence-based practices in online learning: a meta-analysis and review of online learning studies. In: revised report of U.S. Department of Education, Office of Planning, evaluation, and policy development, Washington, D.C., United States. Available at: https://www2.ed.gov/rschstat/eval/tech/evidence-based-practices/finalreport.pdf (accessed 20 June 2022) (2010).

54. Bonnaud-Antignac A, Campion L, Pottier P, Supiot S. Videotaped simulated interviews to improve medical students' skills in disclosing a diagnosis of cancer. *Psychooncology*. (2010) 19:975–81. doi: 10.1002/pon.1649

55. Narula N, Ahmed L, Rudkowski J. An evaluation of the '5 minute medicine' video podcast series compared to conventional medical resources for the internal medicine clerkship. *Med Teach*. (2012) 34:e751–5. doi: 10.3109/0142159X.2012.689446

56. Reed S, Shell R, Kassis K, Tartaglia K, Wallihan R, Smith K, et al. Applying adult learning practices in medical education. *Curr Probl Pediatr Adolesc Health Care*. (2014) 44:170–81. doi: 10.1016/j.cppeds.2014.01.008

57. Guy R, Byrne B, Dobos M. Optional anatomy and physiology e-learning resources: student access, learning approaches, and academic outcomes. *Adv Physiol Educ*. (2018) 42:43–9. doi: 10.1152/advan.00007.2017

58. Choi-Lundberg DL, Cuellar WA, Williams A-MM. Online dissection audio-visual resources for human anatomy: undergraduate medical students' usage and learning outcomes. *Anat Sci Educ*. (2016) 9:545–54. doi: 10.1002/ase.1607

59. Langfield T, Colthorpe K, Ainscough L. Online instructional anatomy videos: student usage, self-efficacy, and performance in upper limb regional anatomy assessment. *Anat Sci Educ*. (2018) 11:461–70. doi: 10.1002/ase.1756

60. Nation H, Kaliski D, Ortiz A. Narrated dissection videos and peer-mentoring to enhance anatomy performance of underrepresented minority students in physical therapy education. *Anat Sci Educ*. (2020) 13:794–9. doi: 10.1002/ase.1971

61. Chinnah TI, De Bere SR, Collett T. Students' views on the impact of peer physical examination and palpation as a pedagogic tool for teaching and learning living human anatomy. *Med Teach*. (2011) 33:e27–36. doi: 10.3109/0142159X.2011.530313

62. Choplin A. *La palpation thérapeutique: lecture ethno-pédagogique. 1st* ed. Saint-Denis, FR: Éditions Connaissances et (2017).

63. Hussler R. *Pédagogie somatopsychique et enseignement de la masso-kinéthérapie*. Strasbourg, FR: Strasbourg University (2015) Doctorate of Education Sciences Dissertation.

64. Muttappallymyalil J, Mendis S, John LJ, Shanthakumari N, Sreedharan J, Shaikh RB. Evolution of technology in teaching: blackboard and beyond in medical education. *Nepal J Epidemiol*. (2016) 6:588–94. doi: 10.3126/nje.v6i3.15870

65. Kay RH. Exploring the use of video podcasts in education: a comprehensive review of the literature. *Comput Hum Behav*. (2012) 28:820–31. doi: 10.1016/j.chb.2012.01.011

66. Yammine K, Violato C. The effectiveness of physical models in teaching anatomy: a meta-analysis of comparative studies. *Adv Health Sci Educ*. (2016) 21:883–95. doi: 10.1007/s10459-015-9644-7

67. Wilkinson T. Primal pictures anatomy teaching resources: 3D anatomy software and 3D real-time viewer. *J Anat*. (2012) 220:118–9. doi: 10.1111/j.1469-7580.2011.01446.x

68. Nuland SEV, Rogers KA. The anatomy of e-learning tools: does software usability influence learning outcomes? *Anat Sci Educ*. (2016) 9:378–90. doi: 10.1002/ase.1589

69. Park S, Kim Y, Park S, Shin J-A. The impacts of three-dimensional anatomical atlas on learning anatomy. *Anat Cell Biol*. (2019) 52:76–81. doi: 10.5115/acb.2019.52.1.76

70. Azer SA, Azer S. 3D anatomy models and impact on learning: a review of the quality of the literature. *Health Prof Educ*. (2016) 2:80–98. doi: 10.1016/j.hpe.2016.05.002

71. Ghosh SK. Cadaveric dissection as an educational tool for anatomical sciences in the 21st century. *Anat Sci Educ*. (2017) 10:286–99. doi: 10.1002/ase.1649

72. Jayakumar N, Brunckhorst O, Dasgupta P, Khan MS, Ahmed K. E-learning in surgical education: a systematic review. *J Surg Educ*. (2015) 72:1145–57. doi: 10.1016/j.jsurg.2015.05.008

73. Pather N, Blyth P, Chapman JA, Dayal MR, Flack NAMS, Fogg QA, et al. Forced disruption of anatomy education in Australia and New Zealand: an acute response to the Covid-19 pandemic. *Anat Sci Educ*. (2020) 13:284–300. doi: 10.1002/ase.1968

74. Iwanaga J, Loukas M, Dumont AS, Tubbs RS. A review of anatomy education during and after the COVID-19 pandemic: revisiting traditional and modern methods to achieve future innovation. *Clin Anat*. (2021) 34:108–14. doi: 10.1002/ca.23655

75. Rossettini G, Rondoni A, Palese A, Cecchetto S, Vicentini M, Bettale F, et al. Effective teaching of manual skills to physiotherapy students: a randomised clinical trial. *Med Educ*. (2017) 51:826–38. doi: 10.1111/medu.13347

76. Choudhury B, Gouldsborough I, Gabriel S. Use of interactive sessions and e-learning in teaching anatomy to first-year optometry students. *Anat Sci Educ*. (2010) 3:39–45. doi: 10.1002/ase.123

77. Derrendinger I. Les nouvelles voies d'accès aux études de santé. *Sages Femmes*. (2020) 19:48–50. doi: 10.1016/j.sagf.2020.03.012

78. Lochner L, Wieser H, Waldboth S, Mischo-Kelling M. Combining traditional anatomy lectures with e-learning activities: how do students perceive their learning experience? *Int J Med Educ*. (2016) 7:69–74. doi: 10.5116/ijme.56b5.0369

79. Singh A, Min AKK. Digital lectures for learning gross anatomy: a study of their efficacy. *Korean J Med Educ*. (2017) 29:27–32. doi: 10.3946/kjme.2017.50

frontiers | Frontiers in Medicine

TYPE Opinion
PUBLISHED 13 October 2023
DOI 10.3389/fmed.2023.1279707

OPEN ACCESS

EDITED BY
Samson Maekele Tsegay,
Anglia Ruskin University, United Kingdom

REVIEWED BY
Rintaro Imafuku,
Gifu University, Japan

*CORRESPONDENCE
Ihsan Nazurah Zulkipli
✉ nazurah.zulkipli@ubd.edu.bn

†These authors have contributed equally to this work and share first authorship

RECEIVED 18 August 2023
ACCEPTED 02 October 2023
PUBLISHED 13 October 2023

CITATION
Alam F, Lim MA and Zulkipli IN (2023) Integrating AI in medical education: embracing ethical usage and critical understanding. *Front. Med.* 10:1279707. doi: 10.3389/fmed.2023.1279707

Integrating AI in medical education: embracing ethical usage and critical understanding

Faiza Alam†, Mei Ann Lim† and Ihsan Nazurah Zulkipli*†

Pengiran Anak Puteri Rashidah Sa'adatul Bolkiah Institute of Health Sciences, Universiti Brunei Darussalam, Bandar Seri Begawan, Brunei

KEYWORDS

generative AI, medical higher education, critical thinking, ethical considerations, healthcare professionals

Introduction

Artificial intelligence, commonly abbreviated as AI, is described as the simulation of human intelligence by machines, giving machines, particularly computer systems, the ability to perform complex tasks that would normally require human reasoning, decision-making, and problem-solving. With advancements in machine learning and deep learning, we can expect to see AI integrated into even more areas of our daily lives. Indeed, AI is becoming increasingly prevalent in healthcare. It can provide personalized recommendations (1) and improve medical diagnostics, particularly in the field of medical imaging (2). At least 11 medical schools across the United States of America, Canada and the Republic of Korea have pilot AI curricula (3). Potentially, all medical schools may need to do the same to keep up with not only the changing landscape of medical education but indeed of medicine itself.

The AI chatbot ChatGPT took the world by storm in late 2022, and higher education institutions are not immune from its repercussions in education. Online education platforms have already started to use generative AI tools, such as Khan Academy via the AI chatbot, Khanmingo, to supplement and personalize student education. It can be used as a personal tutor, a writing coach, and a question generator to test comprehension. It is only a matter of time before brick-and-mortar institutions need to do the same to keep up with the rapidly changing landscape of digital tools in education. Furthermore, Clark and Archibald (4) asserted that the avoidance of the impact of generative AI on higher education results in multi-level harms which range from the lack of structures to ensure scholarly integrity to the stagnation and irrelevance of learning approaches in health science education.

Despite the acceptance of AI in the healthcare profession, concerns such as legal liability and accountability have been raised at the crux of the profession, that is, in making clinical decisions (5). At present, it remains unclear to healthcare professionals who is responsible in the event of errors by AI in clinical decision support systems. Also, it appears that many would not assume accountability for results provided by AI (6). The ethical sense when using AI can be fostered by educators during medical education to facilitate accountable and responsible AI usage by future healthcare professionals.

AI tools in medical education can encompass AI virtual environments, AI-based assessments, and adaptive e-learning systems (7). Additionally, three distinct uses of AI tools in education have been defined in a report by Baker and Smith (8), listed below:

1. Learner-oriented AI—AI technology that "students use to receive and understand new information".

2. Instructor-oriented AI—AI technology that "can help teachers reduce their workload, gain insights about students and innovate in their classroom".
3. Institution-oriented AI—AI technology that "helps make or inform decisions made by those managing and administrating schools or our education system as a whole".

As healthcare education faculty members in a higher education institution, we advocate for the integration of AI tools in medical education, specifically learner-oriented AI tools in this paper. In this article, we focus on learner-oriented tools and propose guidelines for which these tools should be used by medical students.

Impact of AI use in an undergraduate medical program

With the release of ChatGPT late last year, efforts have been made to investigate its utility in education, as well as the utility of other generative AI tools (9–12). However, because of its capabilities, ChatGPT is easily misused, and we outline an observation from our faculty below.

At the Pengiran Anak Puteri Rashidah Sa'adatul Bolkiah (PAPRBS) Institute of Health Sciences at Universiti Brunei Darussalam, undergraduate students of the medicine program are introduced to academic writing as part of the mandatory research module in the curriculum. The module is designed to equip students with the fundamentals to carry out research in science, medicine, and health. For examination, students are expected to report findings scientifically in the form of a written manuscript and oral presentation. Manuscripts are submitted online via the Canvas learning management system and are checked for plagiarism using Turnitin (13).

AI writing had been detected across several pieces of submission, including heavy incorporation of ChatGPT content that gave rise to serious concerns of academic offense. There was evidence of citations to papers which do not exist (an AI phenomenon known as "hallucination"), and the writing was found "nicely summarized generally", but the knowledge was "touched on superficially and not critically". The lack of knowledge depth and critical thinking was also demonstrated during the oral presentation.

In summary, generative AI is a powerful tool and its usage by students is currently creating disconcerting experiences in higher education due to its impact on academic integrity.

Training students and faculty staff for ethical use of AI

Our experience above indicates to us that faculty teaching staff needs to engage with AI in the interest of training medical students and keeping the curriculum current. Students may plagiarize essays from content generated by AI tools, compromising their critical thinking skills and scholarly integrity. To address this, universities should implement strict policies and guidelines for the ethical use of AI applications. They should foster a culture of academic integrity and equip students with the necessary skills to critically evaluate and use AI responsibly. Educators can also provide workshops or training sessions to teach students how to effectively use AI tools, balancing their use with their own unique ideas and voices. This approach promotes originality, independent thinking and accountability alongside technological advancement, and supports the interest and positive attitude that faculty teaching staff and medical students have toward AI (14).

TABLE 1 Ethical issues of generative AI and their potential solutions (19).

Issue	Solution
Opacity and inexplicability	Develop interpretable generative AI algorithms that explain the AI decision-making process
Data privacy and security	Use of encryption technology, access control mechanisms and data anonymization, and de-identification
Personalization and fairness	Develop algorithms that can identify potentially unfair factors and eliminate them while still meeting the needs of the students
Effectiveness and reliability	Improve quality and quantity of data by including diverse data, but still ensuring quality and consistency of labeled data

In the aforementioned undergraduate research module, we propose guiding medical students on how to write effective ChatGPT prompts and use ChatGPT answers to avoid ChatGPT downsides (such as hallucination and phrase inaccuracies), while maintaining academic integrity and writing standards. During the introductory briefing at the start of the module, we strongly encourage our medical educators who are presenting to remind students of two Turnitin features which detect plagiarism—similarity and AI scores. Medical educators and students should be aware that software programs exist to detect AI-generative text and should take measures to avoid plagiarism (15). To promote accountability, we should require students to disclose the use of AI tools in their written manuscript in a manner similar to how we disclose our use of statistical software for data analysis (15, 16).

Elsewhere in the curriculum, AI-related lectures could be introduced to first-year medical students, in which the topics cover basic understanding, benefits and risks of AI, which would allow students to become familiar with common terminology (3, 17). In modules which emphasize biomedical knowledge acquisition and retention, as well as those related to patient care, teaching staff can incorporate large language model-powered chatbots to answer common medical questions for students and patients. Chatbots can also be used by students to practice their clinical communication skills.

Apart from the integration of AI tools in the curriculum, we further propose AI-based research projects to be made available for medical students on the research project and dissertation track of the fourth year of the curriculum at PAPRSB Institute Health Sciences. This proposal is feasible based on collaborations between our medical school and the School of Digital Sciences on campus.

Scientists have tried to use ChatGPT to write scientific manuscripts with varying success (12, 18), while Yu and Guo (19) elaborated on issues to be resolved when using generative AI in education, which we have summarized below together with potential solutions (Table 1). Ethical issues arising from the use of

AI tools such as legal liability and accountability can be discussed in the research module as well as in the medical ethics module in the second year of the curriculum.

Beneficial and ethical usage of AI in medical education

Through our conversations with medical students, we can affirm the common usage of ChatGPT. AI writing tools (such as ChatGPT and QuillBot) are prevalent and readily accessible to students right now, and these can enhance research capabilities, as ChatGPT did for college-educated professionals in improving the quality and enjoyment of their writing tasks (20). For medical students, ChatGPT can be used to provide interactive environments for them to practice their communication skills with simulated patients and another tool, DALL-E, can be used to help them practice their diagnostic imaging skills (9).

The ethics of using AI tools is indeed a prevalent concern today. Medical students need to be guided to think independently and appraise critically as well as ethically despite the convenience of readily generated information. They need to be aware of and steer clear of AI-generated misinformation on biomedical knowledge and the pathophysiology of disease (3, 11), and thereby avoid AI-generated information acting as a crutch for clinical decision-making and hampering clinical reasoning abilities (17).

In summary, toward embracing AI education in the medical curriculum and in keeping the curriculum relevant to ongoing development in AI, faculty teaching staff need to rapidly adapt to the integration of AI tools and develop AI literacy by being trained in multiple AI tools for teaching and assessment.

Conclusion

AI has emerged as a powerful tool in medical education, offering unique opportunities to enhance learning, address knowledge gaps, and improve patient care. Embracing AI in medical education holds immense potential for advancing healthcare and empowering the next generation of future healthcare professionals to enhance patient care, improve outcomes, and contribute to the advancement of medicine. By leveraging the capabilities of AI, medical education can become more personalized and efficient. However, careful attention must be paid to ethical considerations, technical infrastructure, and faculty training to ensure the responsible integration of AI into medical education. Medical education should include dedicated modules or courses that explore the ethical considerations of AI and emphasize the need for transparency and comprehensibility in AI systems to foster trust between students, faculty, and AI technologies.

Author contributions

INZ: Conceptualization, Writing—original draft, review, and editing. FA: Conceptualization, Writing—original draft. MAL: Conceptualization, Writing—original draft, review, and editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Alkhodari M, Xiong Z, Khandoker AH, Hadjileontiadis LJ, Leeson P, Lapidaire W. The role of artificial intelligence in hypertensive disorders of pregnancy: towards personalized healthcare. *Expert Rev Cardiovasc Ther.* (2023) 21:531–43. doi: 10.1080/14779072.2023.2223978

2. Al-Antari MA. Artificial intelligence for medical diagnostics-existing and future AI technology! *Diagnostics.* (2023) 13:688. doi: 10.3390/diagnostics13040688

3. Lee J, Wu AS, Li D, Kulasegaram KM. Artificial intelligence in undergraduate medical education: a scoping review. *Acad Med.* (2021) 96:S62–70. doi: 10.1097/ACM.0000000000004291

4. Clark AM, Archibald MM. ChatGPT: what is it and how can nursing and health science education use it? *J Adv Nurs.* (2023) 79:3648–51. doi: 10.1111/jan.15643

5. Lambert SI, Madi M, Sopka S, Lenes A, Stange H, Buszello CP, et al. An integrative review on the acceptance of artificial intelligence among healthcare professionals in hospitals. *NPJ Digit Med.* (2023) 6:1–14. doi: 10.1038/s41746-023-00852-5

6. Yurdaisik I, Aksoy SH. Evaluation of knowledge and attitudes of radiology department workers about artificial intelligence. *Ann Clin Anal Med.* (2021) 12:186–90. doi: 10.4328/ACAM.20453

7. Sapci AH, Sapci HA. Artificial intelligence education and tools for medical and health informatics students: systematic review. *JMIR Med Educ.* (2020) 6:e19285. doi: 10.2196/19285

8. Baker T, Smith L. *Educ-AI-tion Rebooted? Exploring the Future of Artificial Intelligence in Schools and Colleges.* Artificial Intelligence - EdTech Innovation Fund (2019). Available online at: https://www.nesta.org.uk/report/education-rebooted/ (cited July 26, 2023).

9. Amri MM, Hisan UK. Incorporating AI tools into medical education: harnessing the benefits of ChatGPT and Dall-E. *J Novel Eng Sci Technol.* (2023) 2:34–9. doi: 10.56741/jnest.v2i02.315

10. Currie G, Singh C, Nelson T, Nabasenja C, Al-Hayek Y, Spuur K. ChatGPT in medical imaging higher education. *Radiography*. (2023) 29:792–9. doi: 10.1016/j.radi.2023.05.011

11. De Angelis L, Baglivo F, Arzilli G, Privitera GP, Ferragina P, Tozzi AE, et al. ChatGPT and the rise of large language models: the new AI-driven infodemic threat in public health. *Front Public Health*. (2023) 11:1166120. doi: 10.3389/fpubh.2023.1166120

12. Hisan UK, Amri MM. ChatGPT and medical education: a double-edged sword. *J Pedagogy Educ Sci*. (2023) 2:71–89. doi: 10.56741/jpes.v2i01.302

13. Turnitin. *AI Writing Detection Frequently Asked Questions*. (2023). Available online at: https://www.turnitin.com/products/features/ai-writing-detection/faq (cited September 20, 2023).

14. Wood EA, Ange BL, Miller DD. Are we ready to integrate artificial intelligence literacy into medical school curriculum: students and faculty survey. *J Med Educ Curric Dev*. (2021) 8:23821205211024078. doi: 10.1177/23821205211024078

15. Vintzileos AM, Chavez MR, Romero R. A role for artificial intelligence chatbots in the writing of scientific articles. *Am J Obstetr Gynecol*. (2023) 229:89–90. doi: 10.1016/j.ajog.2023.03.040

16. Flanagin A, Kendall-Taylor J, Bibbins-Domingo K. Guidance for authors, peer reviewers, and editors on use of AI, language models, and Chatbots. *JAMA*. (2023) 330:702–3. doi: 10.1001/jama.2023.12500

17. Ngo B, Nguyen D, vanSonnenberg E. The cases for and against artificial intelligence in the medical school curriculum. *Radiol Artif Intell*. (2022) 4:e220074. doi: 10.1148/ryai.220074

18. Conroy G. Scientists used ChatGPT to generate an entire paper from scratch - but is it any good? *Nature*. (2023) 619:443–4. doi: 10.1038/d41586-023-02218-z

19. Yu H, Guo Y. Generative artificial intelligence empowers educational reform: current status, issues, and prospects. *Front Educ*. (2023) 8:1183162. doi: 10.3389/feduc.2023.1183162

20. Noy S, Zhang W. Experimental evidence on the productivity effects of generative artificial intelligence. *Science*. (2023) 381:187–92. doi: 10.1126/science.adh2586

frontiers | Frontiers in Medicine

TYPE Brief Research Report
PUBLISHED 13 March 2024
DOI 10.3389/fmed.2024.1239916

OPEN ACCESS

EDITED BY
Samson Maekele Tsegay,
Anglia Ruskin University, United Kingdom

REVIEWED BY
Keerti Singh,
The University of the West Indies, Cave Hill, Barbados
Muhammad Azeem Ashraf,
Hunan University, China

*CORRESPONDENCE
Kotaro Takeda
ktakeda@fujita-hu.ac.jp

RECEIVED 14 June 2023
ACCEPTED 27 February 2024
PUBLISHED 13 March 2024

CITATION
Kitamura S, Takeda K, Uehara S, Yoshida T, Ota H, Tanabe S, Takeda K, Koyama S, Sakurai H and Kanada Y (2024) An evaluation of rehabilitation students' learning goals in their first year: a text mining approach. *Front. Med.* 11:1239916. doi: 10.3389/fmed.2024.1239916

An evaluation of rehabilitation students' learning goals in their first year: a text mining approach

Shin Kitamura, Kotaro Takeda*, Shintaro Uehara, Taiki Yoshida, Hirofumi Ota, Shigeo Tanabe, Kazuya Takeda, Soichiro Koyama, Hiroaki Sakurai and Yoshikiyo Kanada

Faculty of Rehabilitation, School of Health Sciences, Fujita Health University, Aichi, Japan

Introduction: Qualitative information in the form of written reflection reports is vital for evaluating students' progress in education. As a pilot study, we used text mining, which analyzes qualitative information with quantitative features, to investigate how rehabilitation students' goals change during their first year at university.

Methods: We recruited 109 first-year students (66 physical therapy and 43 occupational therapy students) enrolled in a university rehabilitation course. These students completed an open-ended questionnaire about their learning goals at the time of admission and at 6 and 12 months after admission to the university. Text mining was used to objectively interpret the descriptive text data from all three-time points to extract frequently occurring nouns at once. Then, hierarchical cluster analysis was performed to generate clusters. The number of students who mentioned at least one noun in each cluster was counted and the percentages of students in each cluster were compared for the three periods using Cochran's Q test.

Results: The 31 nouns that appeared 10 or more times in the 427 sentences were classified into three clusters: "Socializing," "Practical Training," and "Classroom Learning." The percentage of students in all three clusters showed significant differences across the time periods ($p < 0.001$ for "Socializing"; $p < 0.01$ for "Practical Training" and "Classroom Learning").

Conclusion: These findings suggest that the students' learning goals changed during their first year of education. This objective analytical method will enable researchers to examine transitional trends in students' reflections and capture their psychological changes, making it a useful tool in educational research.

KEYWORDS

cluster analysis, professional education, rehabilitation, students, text mining

1 Introduction

Data analysis methods have rapidly evolved in biomedical, life, and social sciences (1). The analytical methods commonly taught in introductory statistics courses (e.g., *t*-test, analysis of variance) have been extensively used. However, their usage has been declining in recent years (1). On the other hand, the use of multivariate statistical and machine learning approaches, though less prevalent than the aforementioned analytical methods, has been expanded due to

the increasing accessibility of large and intricate datasets (2). In recent years, these methods have been applied in educational science. Notably, data mining, the process of extracting patterns and relationships in data from large datasets has been applied to massive student educational datasets to interpret their academic performance (3).

Educational data mining is the application of data mining techniques to educational data, and its objective is to resolve educational research issues (3). Educational data mining is mainly applied to educational tasks such as the analysis and visualization of educational data, providing feedback for supporting instructors, recommending personalized learning contents, predicting student performance, developing a cognitive model for students that includes their skills and knowledges, detecting undesirable student behaviors, and grouping students (3). Recently, with the development of educational software, the expansion of databases of student information, and the development of web-based education such as e-learning, a large amount of information is being generated, and further utilization of educational data is expected (3). The goal of educational data mining is subjective, such as improving the learning process for students. As many different types of data in education have become publicly available in recent years, there has been a need to utilize subtle measurement techniques that can be adapted to a variety of data (4). For example, the evaluation of students' progress and changes in their learning goals cannot only be conducted quantitatively based on numerical data interpretation expressed on an interval or ordinal scale but also through qualitative analysis that includes essential elements that evaluate students' progress and change in their learning goals. In fact, in health professional education, descriptive reports provide reflections and students' self-evaluations, used as a means of professional development, which provides objective information for identifying students' progress (5–7). Text mining is a data mining method that objectively analyzes qualitative data and is being utilized in supportive care for preterm children (8), education of university students, including research on cognitive control functions of students (9) and education of health professionals (10–16). This method contributes to the objective interpretation of text data by modeling important concepts and calculating the co-occurrence of keywords that occur frequently in the text.

Most of the existing text-mining studies on learning in medicine and healthcare focused on medical students (11, 14, 15). These studies have primarily analyzed reflection reports related to learning within specific educational programs, such as clinical practice and off-campus classes, at different points in time. A previous study examining the relationship between students' learning goals and their academic performance demonstrated that text-mining techniques can be employed to identify their goals objectively and systematically, proving valuable in enhancing the understanding of diverse student needs (17). In education, setting learning goals play a crucial role in academic performance (18, 19). It was emphasized that it is important [1] for students to set their own learning goals to foster the awareness of their strengths and weaknesses, and [2] for educators to understand that these goals will change as students learn (20). It has also been demonstrated that, in order to enhance the educational impact of setting learning goals, educational supports are essential in terms of both utilizing these goals and receiving feedback from teachers (21, 22). On the other hand, for a comprehensive assessment of students' development, it is crucial not only to comprehend their learning goals at a particular juncture in the entire educational program but also to track their transitions. However, no study has examined changes in students' learning goals over time using text mining. In summary, there is a scarcity of studies on text mining that specifically target physical therapy students (PTSs) or occupational therapy students (OTSs) and the effects of their long-term learning.

In the present pilot study, we proposed a method that utilizes text mining to track the evolution of students' learning goals in health professional education. We collected descriptive text data at regular intervals from both PTSs and OTSs. By applying text mining to the collected text data across various time periods, our objective was to gain insights into the changes that took place in their learning goals throughout their educational journey.

2 Materials and methods

The present study retrospectively analyzed longitudinal descriptive text data on the learning goals of students in a university rehabilitation course in Japan. The analysis in this study was conducted on text data written in Japanese.

We recruited 109 first-year students who enrolled in the course of PT and OT at the Faculty of Rehabilitation, School of Health Sciences, Fujita Health University, in April 2021. This number includes all first-year students, except those who were repeating the course. Table 1 displays the distribution of students by major and gender. Although PT and OT are different healthcare professions, students receive similar health professional education in the first year at this university, including physiology, anatomy, bioethics, social work, statistics, and physics. Therefore, we did not distinguish between PTS and OTS in the present study. This study was approved by the Ethics Review Committee of Fujita Health University (approval number HM21-377) and conducted in accordance with the Declaration of Helsinki.

The students answered the following open-ended questions at three different time points; that is, at the time of admission (at 0 months), 6 months (after completing the first semester), and 12 months (after completing the first year) on entering school:

Q_{0mo}: What do you want to work on first in school?

Q_{6mo}: What do you want to work on in the second semester of your first year?

Q_{12mo}: What do you want to work on in your second year?

These questionaries were provided using a learning result visualization system in which students periodically self-evaluated their goals and achievements (23). The purpose and content of the questionnaire and the times when the students would be asked to respond were explained to the students prior to the survey. The students responded by typing the text with no time limit, using their own computer tablets on an assigned day. The response time was approximately 20 min.

TABLE 1 Majors and gender of the participating students.

Majors	Male	Female	Total
PTS, *n*	32	34	66
OTS, *n*	13	30	43
Total, *n*	45	64	109

PTS, physical therapy students; OTS, occupational therapy students.

TABLE 2 Basic statistics of text mining.

Category	Metrics
Number of sentences	427
Number of morphemes type	781
Average number of morphemes per response	22
Number of nouns type	281
Number of nouns	1,389
Average number of nouns per response	4

To globally capture the student goals from the descriptive words and their changes throughout the first year of education, text mining and hierarchical cluster analysis (HCA) were performed using a software KH Coder (24, 25) on the text data of the questionnaire responses. As for preparation, one of the authors (SKi) manually corrected typographical errors in each sentence. Text data from all the time periods (Q_{0mo}, Q_{6mo}, and Q_{12mo}) were pooled together. Nouns were detected as a first step in text mining. If synonyms were identified, they were unified into a single word after ensuring that the meaning of the sentence remained unchanged. "Physical therapy" and "occupational therapy" were treated as one word. Words that indicated the timing of the responses, such as "first semester" and "second semester," were excluded. Only nouns whose frequency of appearance was more than 10 across all three time periods were selected for the HCA. Ward's method, which minimizes the total within-cluster variance and maximizes the between-cluster variance, was employed in HCA (26). We classified the nouns into clusters using the agglomeration dissimilarity coefficient based on the Jaccard distance as a measure of cooccurrence for term pairs, and the resultant HCA dendrogram was located by KH Coder (27). The authors (SKi, KoT, SU, TY, HO, and ST) discussed the determination of the threshold of the agglomeration dissimilarity coefficient for easy interpretation and naming of each cluster.

To examine how student goals changed, the number of students who wrote sentences containing at least one noun constituting each cluster was counted for each time period. This helped to examine the change in students' goals within clusters across time periods. Cochran's Q test was used to compare the proportions of students over time in each cluster. McNemar's test was used to compare the three periods within each cluster, with a statistical significance level of 0.05/3 = 0.017 according to the Bonferroni correction. Statistical Package for Social Sciences (SPSS; Version 28, IBM Corp., Armonk, NY, United States) was used for statistical analysis.

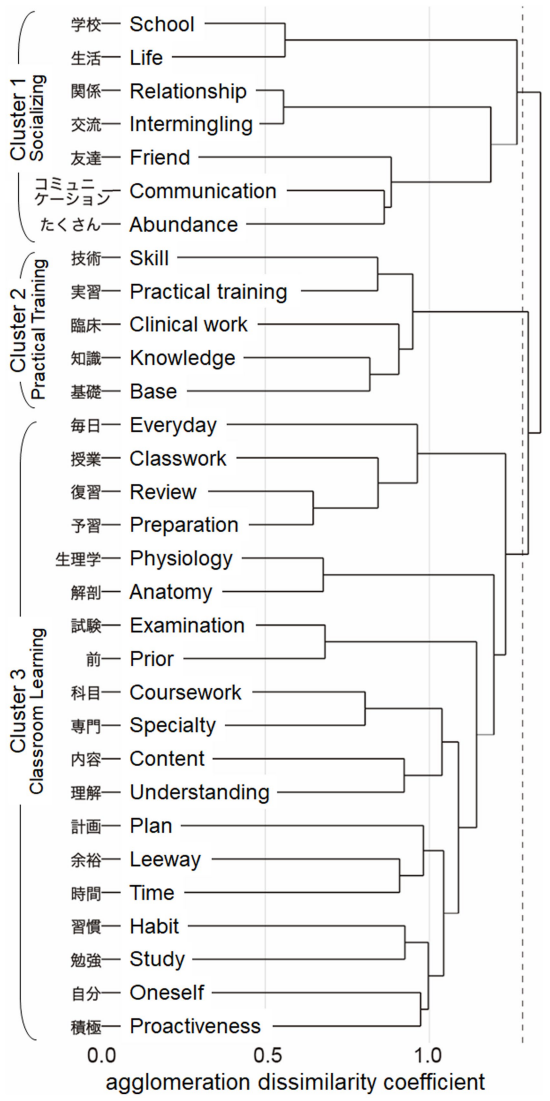


FIGURE 1
Cluster Dendrogram Nouns extracted from the text data of students' responses across all time periods were classified into three clusters: Socializing, Practiced Training, and Classroom Learning. English words corresponding to each Japanese noun are also shown for display purposes. Note that a few Japanese words cannot be expressed with a single English word, but require two words. The dotted vertical line represents the threshold of the agglomeration dissimilarity coefficient (approximately 1.25) that determines the number of clusters.

3 Results

Of the 427 sentences answered by the 109 students, 7,034 words consisting of 781 morphemes were identified. Among these words, 281 nouns, with a total of 1,389 occurrences, were extracted (Table 2). We classified the 31 nouns that appeared more than 10 times into three clusters using HCA. The clusters were named "Socializing," "Practical Training," and "Classroom Learning" (Figure 1).

Figure 2 shows the percentage of students who responded to the words in each cluster at each time period, and Table 3 shows the results of comparisons across the three time periods within clusters. The number of words for the cluster "Classroom Learning" was greater for the majority of students in comparison to other clusters at all time periods. Cochran's Q test showed significant differences in the percentage of the number of students in the three time periods in all clusters: "Socializing," "Practical Training," and "Classroom Learning." The number of students who described the words in the "Socializing" cluster was significantly higher at the time of admission than at any other time points, with less than 2% of students describing the words at Q_{6mo} and Q_{12mo}. The number of students who described words in the cluster "Practical Training" gradually increased over the course of the year and was significantly higher in Q_{12mo} than at the time of admission. The highest number of students who described words for the cluster of "Classroom Learning" was significantly higher at Q_{6mo}than at the time of admission.

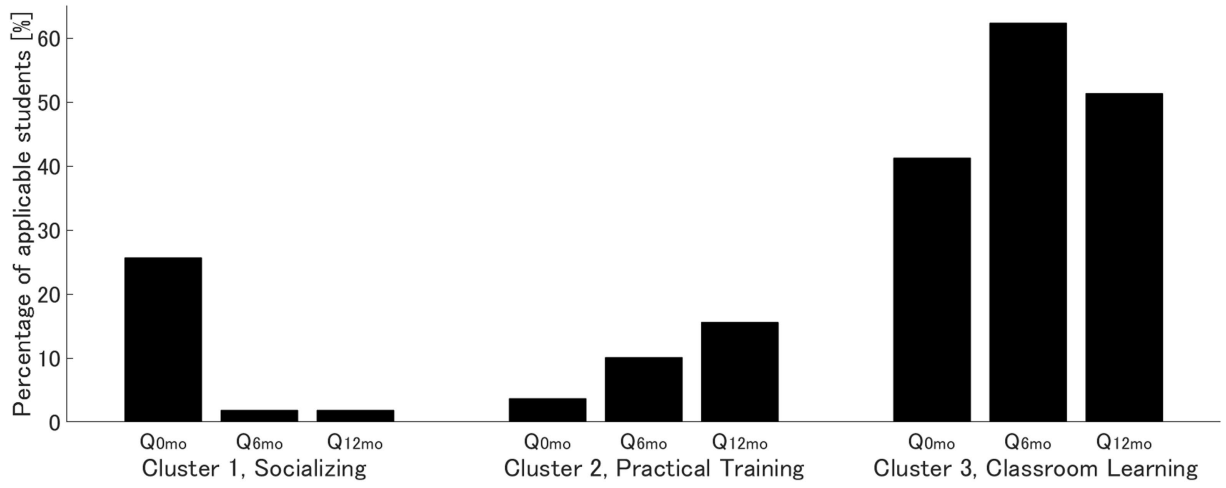


FIGURE 2
Changes in the ratio of applicable students in each cluster The bar graphs represent the percentage of students who responded with words comprising each cluster at each time point (Q_{0mo}, at admission; Q_{6mo}, 6 months later; Q_{12mo}, 12 months later). Note that the sum of the percentages of the three clusters in each period does not add up to 100% because it includes students belonging to more than one cluster or none of the clusters.

TABLE 3 Comparison across three time periods in each cluster.

Cluster	Number of responded students, *n* (%)			Cochran's Q test chi-square (*p* value)	McNemar's test standardized statistic |*z*| (*p* value)		
	Q_{0mo}	Q_{6mo}	Q_{12mo}		Q_{0mo} vs. Q_{6mo}	Q_{0mo} vs. Q_{12mo}	Q_{6mo} vs. Q_{12mo}
Socializing	28 (25.7)	2 (1.8)	2 (1.8)	42.45 (<0.01)	5.62 (<0.01)	5.62 (<0.01)	1.00 (0.00)
Practical Training	4 (3.7)	11 (10.1)	17 (15.6)	10.16 (<0.01)	1.71 (0.08)	3.18 (<0.01)	1.47 (0.14)
Classroom Learning	45 (41.3)	68 (62.4)	56 (51.4)	10.05 (<0.01)	1.51 (0.13)	3.16 (<0.01)	1.65 (0.09)

Percentage of students represents the value relative to the total number of students ($n = 109$). *p*-values in the table are uncorrected.

4 Discussion

This pilot study applied text-mining methods to evaluate rehabilitation students' progress longitudinally. We analyzed descriptive textual data from 109 PTS and OTS about their planned content of focus during their first year of university education at three different time points. Students' responses were grouped and classified into three clusters: "Socializing," "Practical Training," and "Classroom Learning." The percentage of students who responded with the corresponding words differed significantly in the three periods: before, during, and after the first year of education for the three clusters. While previous studies have shown that health professional students' perceptions of learning and attitudes toward professionalism evolve as they progress through higher grades (28, 29), this study clearly demonstrates that students' attitudes on learning, toward the specialization fields, change over the course of a single year by demonstrating changes in their learning goals.

The proportion of students who responded with words associated with the "Socializing" cluster was high at the time of admission and almost disappeared thereafter. At the time of admission, approximately 25% of the students expressed their desire to work on "Socializing," indicating anxiety that the majority of them experienced about interacting with others in the school. This anxiety disappeared within 6 months of admission as new friendships were established.

The proportion of students who responded with words related to the "Practical Training" cluster gradually increased over the course of the year. The first year is crucial for students who aspire to become rehabilitation professionals because they realize the value of professional work (29). It is assumed that the students' motivation to engage in clinical practice gradually increased with exposure to more specialized subjects throughout the year. In addition, the university's curriculum includes a clinical internship for second-year students, which can be a source of anxiety and stress because it involves learning in an environment different from their usual school life (30–34). Thus, the motivation to learn more about "Practical Training" could be attributed to alleviating this anxiety. The students receive more opportunities to study specialized subjects, including clinical internships as they advance to higher grades. Therefore, students' motivation to learn about "Practical Training" will continue to rise once they move on to second grade.

The proportion of students who responded with the words in "Classroom Learning" was higher than the other clusters in all the three response periods, with its peak at 6 months after their admission. This trend is probably due to the abundance of opportunities for fundamental classroom learning in the first year, with the curriculum emphasizing the acquisition of foundational knowledge. The increase in the number of students at the 6 months marks for the words under "Classroom Learning" is attributed to having taken lectures and exams for the first time at the university, which helped in identifying their individual issues and increased their motivation to improve.

Previous studies that used text mining to identify trends in health professional students' experiences and reflections on specific courses,

such as clinical internships, conducted cross-sectional analyses (14–16). While cross-sectional analyses are useful for assessing students' perceptions at a single point in time, longitudinal analyses are required to assess changes in their perceptions over time. In a longitudinal analysis of medical students' reflections, a study compared the occurrence of the four most frequently used words ("responsibility," "pride," "knowledge/skill," and "patient") in their written reflections before, during, and after the clinical exposure program (12). This study found significant changes in the students' perceptions of the characteristics of professionals working in hospitals throughout the program. It is possible to identify general trends in students' psychological changes by examining the progress in the frequency of word occurrence. However, because students may not express their thoughts using the same words, it is appropriate to assess their progress based on themes consisting of multiple words. This provides a more accurate understanding of psychological changes. If text mining is conducted in each assessment period, themes consisting of the same words may not necessarily be generated in each period and it may be difficult to compare themes across periods. Therefore, in the present study, we conducted text mining using data from all time periods (i.e., admission, 6 months, and 12 months). We identified common themes (clusters) throughout the three periods and compared the number of students who expressed at least one noun in sentences comprising each theme across the three time periods. The analytical method proposed in this study will enable a more objective examination of transitional trends in students' reflections and can be utilized in capturing psychological changes in students engaged in university courses such as lectures and clinical internships.

5 Strengths and limitations

The text mining method proposed in this pilot study facilitates objective analysis by quantitatively processing qualitative data. When employing conventional qualitative analysis methods, there exists a potential bias influenced by researchers' experiences and perspectives (35). To address this concern, analytical methods like triangulation have been utilized to ensure validity by incorporating multiple analytical viewpoints, often involving multiple researchers in data analysis. However, this approach can be resource-intensive and impractical for handling substantial data volumes (35). Text mining is a useful analytical approach when objectively analyzing data based on a large sample such as data in educational research. The findings of this text-mining study can be regarded as more objective than those derived from traditional qualitative analysis methods.

The changes in students' learning goals identified in the present study can be used to improve learning support in educational settings. For instance, the finding that approximately 25% of the recruited students set "Socializing" as a goal at the time of admission indicates that it is advisable to provide early support after admission to increase opportunities for communication among students, such as through group work. While "Practical Training" was initially at a relatively low level, awareness gradually increased over the course of the year. However, additional efforts may be needed to further increase awareness in preparation for clinical practice, which commences in the second year. "Classroom Learning" was consistently mentioned by approximately half of the students. It is crucial to convey the importance of subjects related to fundamental learning and their connection with clinical practice to further enhance their awareness. The active involvement of teachers in these transitions in students' attitudes will make learning more motivating and effective.

The proposed method involves extracting words that appeared frequently in the responses from all students. It also evaluates the learning goals mentioned by a substantial number of students and examines their transitional trends. In other words, this approach estimates the overall student trends. In education, personalized learning support may be needed for each student, and it is important to analyze individual goals and their changes. In the future, the proposed method can be applied to further support individual learning by improving the analytical method to quantitatively show individual student characteristics in learning goals by comparing overall trends with individual goals.

6 Conclusion

The present pilot study applied text-mining methods to objectively identify changes in rehabilitation students' learning goals during their first year of education. The study demonstrates that students' learning goals change during their first year at university. The analytical method proposed in this study enables capturing the psychological changes of students and could be a useful method in educational research.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethics Review Committee of Fujita Health University. The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because Informed consent was obtained in the form of an opt-out, and an oral explanation was also given at the time of data collection.

Author contributions

KoT, SKi, and SU contributed to the study concept and design, data analysis and interpretation, and manuscript writing. TY, HO, and ST contributed to the study concept and design, analysis, and interpretation of the data. KaT contributed to the study concept, study design, and data collection. SKo, HS, and YK contributed to the study concept, design, and data interpretation. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Bolt T, Nomi JS, Bzdok D, Uddin LQ. Educating the future generation of researchers: a cross-disciplinary survey of trends in analysis methods. *PLoS Biol*. (2021) 19:e3001313. doi: 10.1371/journal.pbio.3001313

2. Fan J, Han F, Liu H. Challenges of big data analysis. *Natl Sci Rev*. (2014) 1:293–314. doi: 10.1093/nsr/nwt032

3. Romero C, Ventura S. Educational data mining: a review of the state of the art. *IEEE Trans Syst Man Cybern C*. (2010) 40:601–18. doi: 10.1109/tsmcc.2010.2053532

4. Romero C, Ventura S. Educational data mining: a survey from 1995 to 2005. *Expert Syst Appl*. (2007) 33:135–46. doi: 10.1016/j.eswa.2006.04.005

5. Charon R, Hermann N. Commentary: a sense of story, or why teach reflective writing? *Acad Med*. (2012) 87:5–7. doi: 10.1097/acm.0b013e31823a59c7

6. Sandars J. The use of reflection in medical education: AMEE guide no. 44. *Med Teach*. (2009) 31:685–95. doi: 10.1080/01421590903050374

7. Schei E, Fuks A, Boudreau JD. Reflection in medical education: intellectual humility, discovery, and know-how. *Med Health Care Philos*. (2019) 22:167–78. doi: 10.1007/s11019-018-9878-2

8. Park JH, Lee H, Cho H. Analysis of the supportive care needs of the parents of preterm children in South Korea using big data text-mining: topic modeling. *Child Health Nurs Res*. (2021) 27:34–42. doi: 10.4094/chnr.2021.27.1.34

9. Kase T, Kawagoe T. Life skills link to mind wandering among university students: an exploratory study. *Front Psychol*. (2021) 12:729898. doi: 10.3389/fpsyg.2021.729898

10. Brscic M, Contiero B, Schianchi A, Marogna C. Challenging suicide, burnout, and depression among veterinary practitioners and students: text mining and topics modelling analysis of the scientific literature. *BMC Vet Res*. (2021) 17:294–10. doi: 10.1186/s12917-021-03000-x

11. Nakamura K, Kanke S, Hoshi G, Toyoda Y, Yoshida K, Kassai R. Impact of general practice / family medicine clerkships on Japanese medical students: using text mining to analyze reflective writing. *Fukushima J Med Sci*. (2022) 68:19–24. doi: 10.5387/fms.2021-24

12. Shikama Y, Chiba Y, Yasuda M, Stanyon M, Otani K. The use of text mining to detect key shifts in Japanese first-year medical student professional identity formation through early exposure to non-healthcare hospital staff. *BMC Med Educ*. (2021) 21:389. doi: 10.1186/s12909-021-02818-1

13. Uejima T, Ota I, Hamaguchi M, Shigeoka H, Kurita T, Hiraide A. Medical students' perceptions of emergency medical care before and during the coronavirus disease 2019 pandemic. *Acute Med Surg*. (2022) 9:e747. doi: 10.1002/ams2.747

14. Lebowitz A, Kotani K, Matsuyama Y, Matsumura M. Using text mining to analyze reflective essays from Japanese medical students after rural community placement. *BMC Med Educ*. (2020) 20:38–7. doi: 10.1186/s12909-020-1951-x

15. Lin CW, Lin MJ, Wen CC, Chu SY. A word-count approach to analyze linguistic patterns in the reflective writings of medical students. *Med Educ Online*. (2016) 21:29522. doi: 10.3402/meo.v21.29522

16. Nakagawa K, Asakawa Y, Yamada K, Ushikubo M, Yoshida T, Yamaguchi H. Benefits of off-campus education for students in the health sciences: a text-mining analysis. *BMC Med Educ*. (2012) 12:84. doi: 10.1186/1472-6920-12-84

17. Ng HKY. How do students' learning goals differ? A text mining approach to reveal the individual differences. *Front Educ*. (2024) 8:1265193. doi: 10.3389/feduc.2023.1265193

18. Zimmerman BJ, Kitsantas A. Comparing students' self-discipline and self-regulation measures and their prediction of academic achievement. *Contemp Educ Psychol*. (2014) 39:145–55. doi: 10.1016/j.cedpsych.2014.03.004

19. Fryer LK, Ginns P, Walker R. Between students' instrumental goals and how they learn: goal content is the gap to mind. *Br J Educ Psychol*. (2014) 84:612–30. doi: 10.1111/bjep.12052

20. Torok HM, Torre D, Elnicki DM. Themes and characteristics of medical students' self-identified clerkship learning goals: a quasi-statistical qualitative study. *Acad Med*. (2009) 84:S58–62. doi: 10.1097/ACM.0b013e3181b38c71

21. Jiang L, Elen J. Why do learning goals (not) work: a reexamination of the hypothesized effectiveness of learning goals based on students' behaviour and cognitive processes. *Educ Technol Res Dev*. (2011) 59:553–73. doi: 10.1007/s11423-011-9200-y

22. Cheung E. Goal setting as motivational tool in student's self-regulated learning. *Educ Res Q*. (2004) 27:3–9.

23. Kuwaki K. [Assessmentor, a system for visualization of learning outcomes to link to teaching and learning management] Kyougaku management ni tsunageru tame no gakushu seika system "Assessmentor" (in Japanese). *Univ Coll Manag*. (2021) 17:26–34.

24. Higuchi K. A two-step approach to quantitative content analysis: KH coder tutorial using Anne of green gables (part I). *Ritsumeikan Soc Sci Rev*. (2016) 52:77–91.

25. Higuchi K. A two-step approach to quantitative content analysis: KH coder tutorial using Anne of green gables (part II). *Ritsumeikan Soc Sci Rev*. (2017) 52:137–47.

26. Ward JH. Hierarchical grouping to optimize an objective function. *J Am Stat Assoc*. (1963) 58:236–44. doi: 10.1080/01621459.1963.10500845

27. Palmer S. Crowdsourcing customer needs for product design using text analytics In: *Proceedings of the world congress on engineering*. London: (2016)

28. Dunham L, Dekhtyar M, Gruener G, CichoskiKelly E, Deitz J, Elliott D, et al. Medical student perceptions of the learning environment in medical school change as students transition to clinical training in undergraduate medical school. *Teach Learn Med*. (2017) 29:383–91. doi: 10.1080/10401334.2017.1297712

29. Nygren-Bonnier M, Högstedt K, Laurell A, Boström C. First and final year physiotherapy students' expectations of their future profession. *Physiother Theory Pract*. (2022) 39:2366–76. doi: 10.1080/09593985.2022.2075295

30. Beltrán-Velasco AI, Ruisoto-Palomera P, Bellido-Esteban A, García-Mateos M, Clemente-Suárez VJ. Analysis of psychophysiological stress response in higher education students undergoing clinical practice evaluation. *J Med Syst*. (2019) 43:68–7. doi: 10.1007/s10916-019-1187-7

31. Brooke T, Brown M, Orr R, Gough S. Stress and burnout: exploring postgraduate physiotherapy students' experiences and coping strategies. *BMC Med Educ*. (2020) 20:433–11. doi: 10.1186/s12909-020-02360-6

32. Gallasch D, Conlon-Leard A, Hardy M, Phillips A, Van Kessel G, Stiller K. Variable levels of stress and anxiety reported by physiotherapy students during clinical placements: a cohort study. *Physiotherapy*. (2022) 114:38–46. doi: 10.1016/j.physio.2021.12.002

33. Judd BK, Alison JA, Waters D, Gordon CJ. Comparison of psychophysiological stress in physiotherapy students undertaking simulation and hospital-based clinical education. *Simul Healthc*. (2016) 11:271–7. doi: 10.1097/sih.0000000000000155

34. Rezaee M, Rassafiani M, Khankeh H, Hosseini MA. Experiences of occupational therapy students in the first fieldwork education: a qualitative study. *Med J Islam Repub Iran*. (2014) 28:110–5.

35. Patton MQ. Enhancing the quality and credibility of qualitative analysis. *Health Serv Res*. (1999) 34:1189–208.

frontiers | Frontiers in Medicine

TYPE Opinion
PUBLISHED 22 March 2024
DOI 10.3389/fmed.2024.1276839

OPEN ACCESS

EDITED BY
Muhammad Azeem Ashraf,
Hunan University, China

REVIEWED BY
Nadia Shabnam,
National University of Medical Sciences, Pakistan
Usman Mahboob,
Khyber Medical University, Pakistan
Michael J. Wolyniak,
Hampden–Sydney College, United States
Diantha Soemantri,
University of Indonesia, Indonesia
Marko Ćurković,
Sveučilišta u Zagrebu, Croatia

*CORRESPONDENCE
Shaista Salman Guraya
✉ shaist.salman@mbru.ac.ae

RECEIVED 13 August 2023
ACCEPTED 05 March 2024
PUBLISHED 22 March 2024

CITATION
Guraya SS, Rashid-Doubell F, Harkin DW and Guraya SY (2024) Mission-driven e-professionalism in the medical field: shaping digital identity and virtual engagement. *Front. Med.* 11:1276839. doi: 10.3389/fmed.2024.1276839

Mission-driven e-professionalism in the medical field: shaping digital identity and virtual engagement

Shaista Salman Guraya[1]*, Fiza Rashid-Doubell[2], Denis W. Harkin[3] and Salman Yousuf Guraya[4]

[1]Health Professions Education, Institute of Learning, Mohammad Bin Rashid University of Medicine and Health Sciences, Dubai, United Arab Emirates, [2]Retired, Edinburgh, United Kingdom, [3]Faculty of Medicine Health Sciences, Royal College of Surgeons in Ireland, Dublin, Ireland, [4]Clinical Sciences Department, College of Medicine, University of Sharjah, Sharjah, United Arab Emirates

KEYWORDS

e-professionalism, mission, digital identity, social networking sites, digital agency

Introduction

The notion of "e-professionalism" means *"a distinct new paradigm requiring training, codes, and practices"* (1), a definition that differs from conventional professionalism in three distinct ways: first, the contextual variance of the digital context from the *real world*; second, the existing practices of social networking sites (SNSs) that affect a specific style of involvement, diagnostics, or adherence that are not solely under human control; and finally, the peculiar affordance of SNSs where generated content yields a heterogeneous configuration and reconfiguration of human engagement. In general, medical professionalism is considered a social contract between medicine and society and is perceived differently in different societies (2–7). This is further complicated when we consider virtual socialization, where issues are no longer contained by physical boundaries and can be disseminated by a mere touch. Professionalism in this realm appears more perplexing and harder to understand and practice. The construction of digital identity by the innocent sharing of online images, videos, and text narratives of a doctor-patient interaction by a medical student regarding workplace experiences has the potential to compromise the fundamental ethical principles of medical professionalism (8). Still in this open, chaotic, instant, and borderless socialization, medical ethos needs to be maintained and grounded in theory. Hence, the rapidly increased usage of SNSs in medical education demands training, and policies for a regulated application of e-professionalism remain rudimentary (9). Healthcare professionals (HCPs) should be made aware of the myriad possibilities of practices while interacting within SNSs and generating new ways of enactment to safeguard societal contracts (10). To understand the evolving attributes of e-professionalism, we have eluded the concepts of digital natives, digital ecologies and economies, digital competence, and digital agency. These concepts are then gelled into the emerging practice of mission-based e-professionalism in an attempt to embrace the transformation of conventional medical professionalism into the digital realm.

Digital natives and digital identity

The present generations are digital natives, constituting highly qualified personnel in cyberspace with maturing cognition. Currently, online citizenship is permanent, uninterrupted, and uninhibited. However, the mechanisms, correspondence,

communication, and publications of digital content are not well regulated in the absence of proviso. Thus, there are risks attached to the "openness" and connectivity of SNSs. The understanding of professionalism that relates to contextual sensitivity, relativity, and the use of judgment highlights a significant relationship between external behaviors, social expectations, and individual values. Thus, e-professionalism has heightened the substantial role of teaching future HCPs to "*craft and control*" digital identity (8, 11).

Digital "*ecologies*" and "*economies*" of practice

Understanding the SNSs' impulsive, uninhibited, and immersive nature, a certain degree of control needs to be reflected in the professionals' behaviors. We understand that a successful modern practitioner is an expert at negotiating personal and professional identities while conserving the "*ecologies*" and "*economies*" of practices. The inability of digital natives to be digitally professional despite excellent technical knowledge is well known (12). This flashpoint reveals that it is not the lack of knowledge or power of technology but the specific mode of practice inside the technological realm (13). HCPs should be made aware of the possibilities of safe and ethical practices while interacting with SNSs and understand when boundaries of professionalism are being crossed. This shifts the focus from "*practitioner-in-isolation*" to "*practitioner-in-relation*" where mere regulation of professional behaviors will not suffice. Humanistic qualities, with observable behaviors and socialization conducted in the digital context, warrant a holistic appreciation to achieve "*digitally fit*" HCPs. This can be accomplished by educating and training all stakeholders, including medical and health students, faculty, HCPs, and patients, with a passion for working in digital harmony, which can safeguard professional values and behaviors in the medical field.

Are digital natives digitally competent?

Goffman's notion of context collapse demonstrates a notable phenomenon where an individual in a digital context attempts to fulfill the expectations of a versatile audience. Potential consequences of this phenomenon include compromised online communications hampering effective communication, generational points of view leading to socially undesirable enactments, and misreckoning by one or more parties (14, 15). This concept has further stratified the idea of context collapse into "*collusions and collisions*" with the vital distinction of intention. The ubiquity of Internet access, along with the contingent intermingling of virtual spaces, has confirmed that SNSs are not fixed, nor does it determine the emergent phenomenon of human and non-human interactions, where capacity seems to be shared, yet an autonomous vacuum prevails. This "*shared capacity*," where humans and non-humans interpret digital content from a pre-determined perspective, leads to "*knowing-in-practice*" where personal and professional practices lead to the enactment of performative human and material interactions (12). This formation of an autonomous vacuum, providing invisibility and anonymity, can challenge self-efficacy and perceived control, thus giving rise to the concepts of "*technologies-in-practice*" and "*affordances-in-practice.*" These attributes can then be conveniently applied for digital visibility, searchability, persistence of content, replicability, and shareability (16). Young HCPs, although called "*digital natives,*" are helpless when faced with permanency, mixing, interpolation, and shaping of digital content. However, the ability of an individual's agency (self vs. relational) could provide purpose in circumventing architectural affordances during the networked era (17).

Idea of agency in the digital world

One might argue that the concept of legitimate compromise exists in conventional professionalism; however, it is not detrimental to the idea of agency. Rather, it represents change at a societal-institutional level as per Hodges discourse analysis, where decisions are expert-driven, high-tech, high-cost interventions balancing the individual against societal justice, as witnessed during the pandemic (18). Throughout the discourse on conventional professionalism, there remains a responsible individual for making ethical decisions using a specialized skill set and superior knowledge to align with the collective commitment to society. However, the relational agency in the digital world was also narrated by Fenwick (19), who suggested that expertise and responsibilities rely on mutual negotiations of professional practice and that technological artifacts demand a special kind of professional responsibility in the digital world. Keeping the idea of relational agency in mind, digital identity construction can be shaped in a collaborative manner where a "human-material" approach gives a nascent dimension to medical professionalism. In the digital context, the terms "*negotiating identities, maintaining distance, and recognizing and minimizing risk*" have specific meanings related to online interactions and behaviors.

Digital culturally fit

According to Lu's (20) idea of "*culturally fit,*" individuals manifest a smooth interaction with the social environment if equipped with the right values and behaviors. Hence, an HCP who is digitally culturally fit needs to grasp the subtleties of cultural context to grasp the ever-changing cultural norms and expectations (21). Subsequently, a lack of such attributes would impact the individual's wellbeing. A digitally culturally fit HCP demands an understanding of the contextual fluid hierarchical interfaces in the digital realm. Such a frame of reference in the digital context demands a gestalt, responsible for safeguarding our social contract imposed by the complex contradictory demands of the digital self. This reflective view has implications for craft and control phenomena, which again represent shared capacity, distributed agency, and inexplicable human–non-human interactions. This narrative strengthens our pluralist frame of reference in the digital context, asking for a "*body*" responsible for safeguarding our social contract imposed by the complex contradictory demands of the digital self. With the absence of role models, a distinct void in the digital world appears, indicating the inadequacy of a professional identity formation framework

for the empowered individual who can act beyond conventional physical realms. In addition, a behavior-based framework, along with its observable behavioral manifestations, creates a complex mix of cognitive, attitudinal, and personality characteristics that become vacant in the setting of collapsing contexts. While a value-based framework linked to morality and rooted in culture seems incomplete when every tweet and post, assembled and recontextualized in a piecemeal manner, is processed by artificially intelligent software.

Mission and *"principled conscience"*

As described in Kohlberg and Kramer's (22) six stages of moral development, mission supports the view that attributes of e-professionalism are likely to arise during complex digital interactions, thus encompassing social orientation paradigms. Our recent study has presented a new set of findings that emerged from the field of transpersonal psychology with the multi-dimensionality of the required attributes in a digitally professional individual in the form of the Medical Education e-Professionalism (MEeP) framework (10). In this study, the "*mission*" was synonymous with the "*principled conscience*," where understanding social mutuality and a genuine interest in others' welfare is based on the universal principles of respect and the demands of individual conscience (22). However, long before the saturation of SNSs, Boucouvalas articulated the importance of mission as being *"the experience of being part of meaningful wholes and in harmony with superindividual units such as family, social group, culture and cosmic order"* (23). Therefore, to accelerate moral maturity, we need the concept of "*mission*" to connect the philosophical literature of character (e.g., conformative, benevolent, universalist, and integrity), which manifests as observable qualities (e.g., tolerant, powerful, and a good communicator) by individuals who are not only cognitively aware but emotionally connected with qualities of self (e.g., reflection, conscientiousness, self-direction, and actualization).

Relational agency and understanding of mission

The idea of "*relational agency*" and "*mission*" yields a professional individual who understands the desired attributes along with mutual adjustments of virtues, philosophical doctrine and specialized knowledge of systemic, relational, and material aspects of professional responsibility. As we understand, "mission" harnesses the concept of "*cybercivility*" which denotes a positive and inclusive digital culture, ensuring that individuals uphold professional values and demonstrate professionalism even in virtual environments (24). This "*mission*" grants freedom to "*self*" from unitarist rules and moral imperatives by bringing a concept of status that demands a situated and collective web of commitments to make legitimate compromises through balancing conflicting values and priorities.

Recommendations

This review emphasizes a critical concern regarding the necessity for HCPs to embody a diverse range of attributes from various models of medical professionalism. There is an inadequacy of simplistic and binary classifications for complex human experiences in the digital context, emphasizing the need for a holistic understanding of humanistic qualities and observable behaviors within digital socialization. We recommend a nuanced approach to digital professionalism, acknowledging the complexities and dynamics of digital interactions. Due to the risks associated with the openness and connectivity of SNSs, there is a need for a pluralist approach to developing HCPs prepared for the digital realm. This will draw on insights from the MEeP framework and acknowledge the contextual variances in the digital context (12). Additionally, the article recommends values essential for discerning appropriate digital behaviors, emphasizing the importance of context-dependent judgment. Finally, due to the substantial value of self-awareness, emotional intelligence, and reflective practice in navigating the challenges of the digital world, this research recommends that medical educators equip learners with tools for conscientiousness and actualization in the digital realm.

Final opinion

We summarize the modeling of digital identity and virtual engagement using mission-driven e-professionalism in the medical field with three distinct and recognizable elements: "*solidification*" of identities by an understanding of "*mission,*" "*digitally cultural fitness*" with an understanding of the contextually fluid hierarchical interfaces, and an understanding of "*shared agency*" leading to new "*knowing-in-practices*" where personal and professional practices are an enactment of performative human and material interactions. This understanding is an absolute requirement for early career HCPs to safeguard patients' interests and their trust in their profession.

Author contributions

SSG: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Visualization, Writing – original draft, Writing – review & editing. FR-D: Conceptualization, Supervision, Validation, Writing – review & editing. DH: Conceptualization, Supervision, Validation, Writing – review & editing. SYG: Conceptualization, Supervision, Validation, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

References

1. Cain J, Romanelli F. E-professionalism: a new paradigm for a digital age. *Curr Pharm Teach Learn.* (2009) 1:66–70. doi: 10.1016/j.cptl.2009.10.001

2. Cruess RL, Cruess SR. Teaching professionalism: general principles. *Med Teach.* (2006) 28:205–8. doi: 10.1080/01421590600643653

3. Cruess SR. Professionalism and medicine's social contract with society. *Clin Orthop Relat Res.* (2006) 449:170–6. doi: 10.1097/01.blo.0000229275.66570.97

4. Ho M-J, Yu K-H, Hirsh D, Huang T-S, Yang P-C. Does one size fit all? Building a framework for medical professionalism. *Acad Med.* (2011) 86:1407–14. doi: 10.1097/ACM.0b013e31823059d1

5. Al-Eraky MM, Chandratilake M. How medical professionalism is conceptualised in Arabian context: a validation study. *Med Teach.* (2012) 34:S90–5. doi: 10.3109/0142159X.2012.656754

6. Curković M, Borovečki A. *The Bridge Between Bioethics and Medical Practice: Medical Professionalism*. New York, NY: Springer Nature (2022). doi: 10.1007/978-3-031-09733-1

7. Curković M, Casalone C. Medical professionalism—philosophical framework. In: Curković M, Borovečki A, editors. *The Bridge Between Bioethics and Medical Practice: Medical Professionalism*. New York, NY: Springer Nature (2022), p. 113–59. doi: 10.1007/978-3-031-09733-1_6

8. Vukušić Rukavina T, Viskić J, Machala Poplašen L, Relić D, Marelić M, Jokic D, et al. Dangers and benefits of social media on e-professionalism of health care professionals: scoping review. *J Med Internet Res.* (2021) 23:e25770. doi: 10.2196/25770

9. Ellaway RH, Coral J, Topps D, Topps M. Exploring digital professionalism. *Med Teach.* (2015) 37:844–9. doi: 10.3109/0142159X.2015.1044956

10. Guraya SS, Guraya SY, Harkin DW, Ryan Á. Mat Nor MZb, Yusoff MSB. Medical Education e-Professionalism (MEeP) framework; from conception to development. *Med Educ Online.* (2021) 26:1983926. doi: 10.1080/10872981.2021.1983926

11. Kleppinger CA, Cain J. Personal digital branding as a professional asset in the digital age. *Am J Pharm Educ.* (2015) 79:79. doi: 10.5688/ajpe79679

12. Guraya SS, Yusoff MSB, Rashid-Doubell F, Harkin DW, Al-Amad SH, Fredericks S, et al. Changing professional behaviors in the digital world using the medical education e-professionalism (MEeP) framework—a mixed methods multicentre study. *Front Med.* (2022) 9:795. doi: 10.3389/fmed.2022.846971

13. Dobson E, Patel P, Neville P. Perceptions of e-professionalism among dental students: a UK dental school study. *Br Dent J.* (2019) 226:73–8. doi: 10.1038/sj.bdj.2019.11

14. Marwick AE, Boyd D. I tweet honestly, I tweet passionately: twitter users, context collapse, and the imagined audience. *New Media Soc.* (2011) 13:114–33. doi: 10.1177/1461444810365313

15. Davis JL, Jurgenson N. Context collapse: theorizing context collusions and collisions. *Inf Commun Soc.* (2014) 17:476–85. doi: 10.1080/1369118X.2014.888458

16. Costa E. Affordances-in-practice: an ethnographic critique of social media logic and context collapse. *New Media Soc.* (2018) 20:3641–56. doi: 10.1177/1461444818756290

17. Oliver M. The problem with affordance. *E-Learn Digit Media.* (2005) 2:402–13. doi: 10.2304/elea.2005.2.4.402

18. Zaidi Z, Razack S, Kumagai AK. Professionalism revisited during the pandemics of our time: COVID-19 and racism. *Perspect Med Educ.* (2021) 10:238–44. doi: 10.1007/S40037-021-00657-W

19. Fenwick T. Social media, professionalism and higher education: a sociomaterial consideration. *Stud High Educ.* (2016) 41:664–77. doi: 10.1080/03075079.2014.942275

20. Lu L. "Cultural fit": individual and societal discrepancies in values, beliefs, and subjective well-being. *J Soc Psychol.* (2006) 146:203–21. doi: 10.3200/SOCP.146.2.203-221

21. Kim Y, Sohn D, Choi SM. Cultural difference in motivations for using social network sites: a comparative study of American and Korean college students. *Comput Human Behav.* (2011) 27:365–72. doi: 10.1016/j.chb.2010.08.015

22. Kohlberg L, Kramer R. Continuities and discontinuities in childhood and adult moral development. *Hum Dev.* (1969) 12:93–120. doi: 10.1159/000270857

23. Boucouvalas M. Revisiting the concept of self in self-directed learning: toward a more robust construct for research and practice in a global context. *Int J Self-Direct Learn.* (2009) 6:1–10.

24. Guraya SS, Guraya SY, Yusoff MSB. Preserving professional identities, behaviors, and values in digital professionalism using social networking sites; a systematic review. *BMC Med Educ.* (2021) 21:1–12. doi: 10.1186/s12909-021-02802-9

frontiers | Frontiers in Medicine

TYPE Original Research
PUBLISHED 17 April 2024
DOI 10.3389/fmed.2024.1347317

OPEN ACCESS

EDITED BY
Samson Maekele Tsegay,
Anglia Ruskin University, United Kingdom

REVIEWED BY
Pia Caduff,
Retired,
Herrenschwanden, Switzerland
Rachida Soulaymani,
Ministry of Health, Zambia

*CORRESPONDENCE
Francesco Schievano
✉ francesco.schievano@univr.it

RECEIVED 30 November 2023
ACCEPTED 21 March 2024
PUBLISHED 17 April 2024

CITATION
Schievano F, Mwamwitwa KW, Kisenge S, Mmari E, Duga A, Nhlabatsi S, Elagbaje C, Abiola AS, Meshesha SG, Pagani S, Lora R, Sabaini A, Cobelens F, Härmark L, Eko EB, Conforti A, Venegoni M, Magro L and Moretti U (2024) Development, assessment and educational impact of a blended e-learning training program on pharmacovigilance implemented in four African countries.
Front. Med. 11:1347317.
doi: 10.3389/fmed.2024.1347317

Development, assessment and educational impact of a blended e-learning training program on pharmacovigilance implemented in four African countries

Francesco Schievano[1]*, Kissa W. Mwamwitwa[2], Seth Kisenge[2], Elice Mmari[3], Alemayehu Duga[4,5,6], Siphesihle Nhlabatsi[5], Cassandra Elagbaje[7], Abiodun Sadikat Abiola[8], Solomon Getnet Meshesha[9], Silvia Pagani[10], Riccardo Lora[11], Alberto Sabaini[11], Frank Cobelens[12], Linda Härmark[13], Eric Battey Eko[1], Anita Conforti[1], Mauro Venegoni[1], Lara Magro[1] and Ugo Moretti[1]

[1]Section of Pharmacology, Department of Diagnostics and Public Health, University of Verona, Verona, Italy, [2]Section of Clinical Trials Control and Pharmacovigilance, Tanzania Medicines and Medical Devices Authority (TMDA), Dar es Salaam, Tanzania, [3]KNCV Tuberculosis Foundation, Dar es Salaam, Tanzania, [4]Doctoral School Societies, Politics, Public Health, Pharmacoepidemiology and Pharmacovigilance, University of Bordeaux, Bordeaux, France, [5]National Pharmacovigilance Center, Eswatini Ministry of Health, Mbabane, Eswatini, [6]Baylor College of Medicine Children's Foundation-Eswatini, Mbabane, Eswatini, [7]KNCV Tuberculosis Foundation, Abuja, Nigeria, [8]National Agency for Food and Drug Administration and Control (NAFDAC), Abuja, Nigeria, [9]Armauer Hansen Research Institute (AHRI), Addis Ababa, Ethiopia, [10]Unit of Medicine, Hospital of Vimercate, Vimercate, Italy, [11]MedBrains, Department of Computer Science, University of Verona, Verona, Italy, [12]Department of Global Health and Amsterdam Institute for Global Health and Development, Amsterdam University Medical Centers, University of Amsterdam, Amsterdam, Netherlands, [13]Netherlands Pharmacovigilance Centre Lareb, 's-Hertogenbosch, Netherlands

Introduction: Efforts to improve medication access in low-and middle-income countries, particularly in Sub-Saharan Africa, have made progress, especially in the fight against infectious diseases such as tuberculosis. However, challenges exist in establishing effective pharmacovigilance systems. The PhArmacoVIgilance Africa (PAVIA) project was committed to enhancing pharmacovigilance in Tanzania, Eswatini, Nigeria, and Ethiopia, with an emphasis on anti-tuberculosis drugs, utilizing various methods, including training. This study evaluates the PAVIA training program's effectiveness and its adaptation during the COVID-19 pandemic.

Methods: A blended e-learning program, incorporating two courses and a platform for educational materials, was developed. This program, designed to train healthcare professionals in pharmacovigilance, was incorporated into a Training of Trainers model. To evaluate the program effectiveness, we used multiple measures such as assessing knowledge gain through pre-and post-test scores, assessing learners' satisfaction and attitudes via questionnaires, and analyzing Individual Case Safety Reports (ICSRs) in VigiBase to determine the impact on spontaneous reporting systems in the PAVIA countries.

Results: 121 learners enrolled in the pilot trainings, including 36 from Tanzania, 34 from Eswatini, 25 from Nigeria, and 26 from Ethiopia. Notably, post-test scores were significantly higher than pre-test scores in all four countries.

Following the pilot trainings, multiple step-down training sessions were held in Tanzania, Eswatini, and Nigeria, with a total of 827 learners registering and 421 successfully completing the program. Learners' scores on the post-tests were significantly higher than on the pre-tests for both courses in all three countries. Learners' feedback on the training was overwhelmingly positive. Additionally, a qualitative analysis of ICSRs revealed a substantial increase in reports after the training in Tanzania, Eswatini, and Nigeria.

Discussion: An innovative e-learning program trained healthcare professionals in pharmacovigilance and anti-tuberculosis drug safety over 3 years in four PAVIA countries. The program effectively improved participants' knowledge, received positive feedback, and likely had an impact on reporting rates in Tanzania, Eswatini, and Nigeria, although a direct causal link could not be definitively established due to data limitations and other factors, such as the heightened reporting rates associated with COVID-19 vaccines, that could have contributed to the notable increase in ICSRs.

KEYWORDS

pharmacovigilance, blended-learning, tuberculosis, cascade training, Africa

Introduction

In recent years, the World Health Organization (WHO) has worked relentlessly in close collaboration with international partners, research institutions, donors and partners from the private sector to improve global accessibility and availability of medicines, vaccines and other health products (1). Evidence shows that there has been a notable increase in the availability and utilization of a wide range of essential medications in low-and middle-income countries (LMICs) (2). This has been especially true for sub-Saharan Africa (SSA) countries, which bear the highest burden of diseases worldwide, where people have strongly benefitted from the expanded access to newer and established medicines against infectious conditions such as AIDS/HIV, malaria and tuberculosis (TB). In 2015 bedaquiline, a newly launched drug for the treatment of drug-resistant tuberculosis (DR-TB), was included in the TB treatment programs in South Africa and Tanzania (3, 4). Delamanid, another recently approved anti-TB drug for DR-TB, was first recommended in 2014 by the WHO (5). Since then delamanid has been used under different conditions in a number of SSA countries, including Tanzania, Eswatini, Nigeria and Ethiopia (6). The most recent drug for the treatment of highly DR-TB is pretomanid, which is used in combination with bedaquiline and linezolid (7). Pretomanid has been already approved or is undergoing the approval process in various SSA countries, including Ethiopia and Nigeria, where regulatory approval submission is underway (8).

As the number of individuals who gain access to new and better therapeutics keeps growing at a fast pace in LMICs, so does the need for monitoring drug safety through accurate pharmacovigilance (PV) processes.

Although every single phase of the life cycle of a drug, including the so-called pre-marketing phase, requires attentive monitoring of drug safety, post-marketing safety surveillance of drugs acquires particular relevance as conditions of drug use are different from those commonly seen during the pre-marketing phase. Before reaching the market, medicines go through a developing process that includes multiple clinical trials, during which their efficacy and safety are tested and monitored under controlled conditions for a relatively limited length of time. Such conditions cannot be replicated in a real-world setting, where the same medicines become widely available to a huge number of different subpopulations (9). At this point, post-marketing PV comes into play (10).

To ensure the effective surveillance of drug safety and the timely detection of potential issues that may arise from their use, maintaining a thorough and robust PV system is imperative. Operating a well-functioning PV system needs financial and technical resources which are often deficient in SSA countries (11). A comprehensive assessment of PV systems of SSA countries conducted in 2011 found that 87% of such countries did not have a functional PV system. In contrast, only 4 out of 46 SSA countries could rely on a performing PV system capable of detecting, evaluating, and preventing medicine safety issues (12).

PhArmacoVIgilance Africa (PAVIA) was a consortium comprising 13 international partners operational from 2018 to 2023, funded by the European Developing Countries Clinical Trials Partnership (EDCTP). The PAVIA Project, led by the Amsterdam Institute for Global Health and Development (AIGHD), had a primary goal of enhancing drug safety monitoring and strengthening PV processes in four SSA countries: Ethiopia, Eswatini, Nigeria, and Tanzania. It included five Work Packages.[1] The project placed particular emphasis on actively surveilling the safety of anti-TB drugs, a responsibility carried out by the National Tuberculosis Programs (NTPs).

When examining the healthcare landscape in African countries, literature consistently points out a set of enduring challenges. These encompass the shortage of skilled healthcare professionals (HCPs) and their inadequate retention, underdeveloped healthcare infrastructure,

1 https://pavia-africa.net/

low levels of PV awareness among HCPs, and the vulnerability of regulatory and legal frameworks. Notably, one of the most formidable hurdles to PV progress in resource-limited environments is the shortage of personnel trained in PV (13, 14).

In 2018, the PAVIA team conducted a baseline assessment of PV systems and NTPs in Eswatini, Ethiopia, Nigeria, and Tanzania. The strengths and challenges of these systems were assessed, with a focus on their capacity to monitor safety of medicines registered and not registered by the National Medicines Regulatory Authorities (NMRAs) for the treatment of DR-TB. The assessment revealed that all countries had a national health policy in place. A national drug policy was available in three of the four countries, but as part of the health policy in Ethiopia. All four countries had spontaneous reporting systems in place, although these received few reports. Eswatini had a national pharmacy policy, but not a drug policy. A standalone pharmacovigilance policy was enforced in Nigeria and Tanzania. Acts providing for the establishment of the NMRA were in place in all four countries. Overall, this assessment, which encompassed various indicators, highlighted that, while most countries had established laws, regulations, and guidelines for PV, the ability of national PV systems to effectively prevent adverse drug reactions (ADRs) remained limited due to several obstacles, including confusion about roles and responsibilities for the PV of new medicines and duplication of efforts (15).

Addressing these issues hinges on delivering targeted interventions to scale up training and mentoring of local HCPs and PV stakeholders that are part of the PAVIA project's wider strategy to enhance post-marketing surveillance capacity in these countries.

Until recently, medical education of HCPs in resource-constrained SSA countries had mostly relied on traditional face-to-face didactic formulas. However, in last decade the need to scale-up an over-burdened and often inadequate educational infrastructure combined with a rapid and extensive spread of mobile technology in Africa have led to the broad adoption of novel learning approaches such as e-learning (16).

E-learning is defined as the use of information technology or Internet for learning activities. It is a flexible, time-saving, cost-saving approach that allows students to easily access contents from anywhere, at any time (17).

A blended e-learning training approach can be developed by integrating components from both traditional training methods and fully online learning, harnessing the strengths of each while overcoming their respective limitations (18). Several studies in the literature have underscored the efficacy of blended e-learning programs. The adoption of blended e-learning programs in resource-constrained SSA countries has resulted in notable cost savings and enhanced knowledge acquisition for training HCPs (19–24).

Combining a blended e-learning with a Training of Trainers (ToT) framework represents an effective way to scale up training of HCPs. This model involves initially training a group of learners to become trainers who can then impart their knowledge to multiple student groups. The ToT scheme is particularly well-suited for resource-constrained settings due to its cost-effectiveness and its ability to rapidly and comprehensively enhance the skills of HCPs (25, 26).

The present work aimed at evaluating the effectiveness of a blended e-learning-based ToT program comprising two courses designed to train HCPs on PV general principles and anti-TB drugs safety in the four PAVIA countries. Additionally, a comparison between the implementation of the program prior and after the beginning of the COVID-19 pandemic was made. The program was part of a broader strategy set up by PAVIA to promote PV in SSA countries.

Materials and methods

Development of a web-based application for the e-learning program

A web-based application named Schoolroom was developed by MedBrains, a spin-off born within the University of Verona.[2] The specific aim was to provide tutors and learners with a user-friendly platform for easily managing their online classrooms and accessing e-learning materials, respectively. To improve content accessibility in settings where Internet connectivity is still limited or even totally absent, Schoolroom was adapted for both online and offline use. Thus, e-learning materials were made available either via web or through a specific desktop version of the application which was pre-installed on USB memory sticks that were subsequently distributed to tutors. An internet connection was only necessary for initial access to the e-learning courses and for sharing user's results with tutors. After the initial access, users could complete both courses offline.

Thanks to its versatility, the web application could be used on various devices, including smartphones and personal computers, with compatibility depending on the device's browser. For an optimal browsing experience, we recommended users to use Google Chrome on Android devices, Windows/Mac PCs, and Safari on iPhone and iPad devices.

Both versions of Schoolroom required users to sign in with their own credentials. Credentials were provided by tutors to learners at the end of each first session of the training. Upon logging in, users had the option to access various sections within the application or perform specific functions based on their assigned roles.

Schoolroom included three areas, namely (1) Users, (2) Statistics and (3) Courses areas. Users with appropriate permissions could register new users and assign them specific roles in the (1) Users area. Individual or clustered data on users learning progresses were displayed in the (2) Statistics area. Finally, the (3) Courses area served as an interactive area where learners could access all e-learning materials.

Schoolroom allowed five roles to be assigned to users, each one with different view/edit permissions and privileges: (1) Administrator, (2) Tutor, (3) Sub-Tutor, (4) Participant and (5) Observer. (1) Administrators could access all Schoolroom areas and assign Tutor role to designated users. (2) Tutors could enroll and assign users as Participants; they could also check Participants progresses in courses within the Statistics area at any time. (3) Sub-Tutors could create and manage their own classes of Participants. (4) Participants were allowed to access all e-learning materials within the Courses area but could not view content located in other areas. Finally, (5) Observers had limited access permissions and were only allowed to enter the Statistics area.

2 https://www.medbrains.it/en/

The e-learning courses

Two e-learning courses were developed: "The Basic Concepts in Pharmacovigilance" course (Course 1) and "An Overview of Tuberculosis and Anti-Tuberculosis Drug Safety Issues, Monitoring and Management (aDSM)" course (Course 2). The two courses covered different topics related to passive and active surveillance from both a global and a local perspective. Specifically, the first course described the basic principles of PV (Supplementary Table 1), while the second course focused on anti-TB drugs and their management, active surveillance of anti-TB drugs (Supplementary Table 2). It was estimated that each course would take about 3 h to complete.

Each course included both a non-country-specific introductory part and an additional country-specific section. Each part was further subdivided into a subset of educational modules expressly designed in a self-study format.

Each educational module had objectives specific to the module, key-points to summarize the module contents, special sections called "Practical Approach" containing practical advice for the learner, color images and tables as needed, clickable links to external web sources, up-to-date, guidelines and a list of references. This division of the course content into smaller units was designed to expedite the learning process while ensuring that students gained a comprehensive understanding of the subject. Along with educational modules, the e-learning courses incorporated two interactive modules per course, each presenting a different clinical case-based assignment that learners were asked to solve.

To assess learners pre-existing and acquired post-course knowledge, a pre-test and a post-test were included at the beginning and at the end of each of the two e-learning courses. Both used 10 identical, multiple-choice questions randomly generated by the web-based application where e-learning materials were uploaded.

Furthermore, each module included its own intermediate test comprising two multiple-choice questions. These intermediate tests were obligatory, requiring learners to answer the questions to proceed to the next module.

Implementing the train of trainers scheme

In order to expand the training of the local healthcare workforce and reach a maximum number of HCPs, we incorporated our blended e-learning package into a ToT scheme for the implementation in the four PAVIA countries. The underlying rationale for this decision was that a ToT-based blended e-learning program could equip the initial group of local HCPs with the skills and knowledge required to effectively train a second group, potentially setting off a training cascade. The HCPs initially trained were expected to assume the role of trainers in the second phase of the ToT scheme.

On this account, we established two distinct implementation levels or stages for our strategy:

- a first level that involved a multi-day pilot training program with a blended e-learning approach, specifically designed for an initial group of potential trainers;
- a second level that involved newly trained tutors (defined as sub-tutors) who would instruct multiple cohorts of HCPs through an extended version of the pilot training course.

While the initial plan was for all first-level pilot training programs to be conducted on-site by our team, this was only feasible in the case of Tanzania. Due to travel limitations imposed by the COVID-19 pandemic, making it impossible to travel to Africa, all other pilot training programs incorporated sessions delivered through a widely used videoconferencing platform.

Assessment of the training program

We identified the following measures for assessing the effectiveness of our training program:

- The primary evaluation outcome was the knowledge gain resulting from the completion of the e-learning courses. This was assessed by measuring differences in learners' post-test and pre-test scores, using a paired Student's t-test.
- We also assessed learners' satisfaction with the training package and potential changes in individual attitudes toward PV after the training. These were assessed using an online evaluation questionnaire (Supplementary Table 3) and an online attitude questionnaire (Supplementary Table 4), which were both administered to learners at the end of each training. Both questionnaires utilized a Likert scale to measure learners' satisfaction with the training programme and attitude toward PV. The evaluation questionnaire comprised four multiple-choice grid questions designed to measure learners' satisfaction with the usability of the e-learning platform, the e-learning content, and the teaching methodology. Additionally, two single-choice questions collected feedback from learners regarding the availability of an Internet connection during the training and the type of device used to access the e-learning content. The attitude questionnaire included five multiple-choice grid questions and a single-choice question, with a focus on assessing learners' attitudes toward PV and the spontaneous reporting of ADRs.
- Finally, we performed a qualitative analysis of the Individual Case Safety Reports (ICSRs) that were entered into VigiBase, the WHO global database of ICSRs, by the National Pharmacovigilance Centers of the PAVIA countries before and after the pilot trainings. This analysis aimed to evaluate the potential impact of our strategy on the spontaneous reporting systems of these countries. Specifically, a comparison was made between the number and type of ICSRs (encompassing both drugs-related and vaccines-related ICSRs, including COVID-19 vaccines-related) entered into VigiBase 1 year before and 1 year after the pilot trainings. ICSRs of Tanzania, Eswatini, and Nigeria were downloaded from VigiBase and characterized in terms of ADRs seriousness and reporter qualification. The analysis of ICSRs entered into VigiBase by the Ethiopia National Pharmacovigilance Centre could not be performed due to the non-implementation of the step-down trainings, stemming from organizational hurdles, which led to the creation of a limited pool of potential reporters.

Further, we computed the percentage of ICSRs associated with anti-TB drugs based solely on the number of ICSRs that were linked to drug treatments.

All data related to the ICSRs of interest were obtained via VigiLyze, the web-based ICSRs data management system managed by the WHO Uppsala Monitoring Centre (27).

Results

We conducted the PAVIA pilot training in Dar Es Salaam, Tanzania, in October 2019 (Supplementary Table 5). As the sole pilot training conducted before the onset of the COVID-19 pandemic, this training was also the only one to incorporate face-to-face sessions. A total of 36 learners attended the 5-days blended e-learning-based training, which combined face-to-face sessions delivered by three Italian tutors and one local tutor and e-learning-based sessions during which learners were required to go through the two PAVIA e-learning courses. All learners ($n = 36$) passed the post-tests at the end of each course. Throughout the course, participants interacted with each other and the local coordinators, posing targeted questions to the tutors about the content. As part of a test simulating the implementation of the ToT scheme, all participants successfully enrolled students in the Schoolroom platform. Additionally, a PV comedy (performed in Swahili) was created, where two students humorously portrayed a scenario in which a patient reported an ADR to his/her general practitioner.

Similarly, a multi-day pilot training program was implemented and adopted in all other countries.

In April 2021, the Eswatini pilot training was conducted remotely due to international travel restrictions imposed worldwide during the COVID-19 pandemic. In-person sessions were replaced with virtual sessions that were delivered via a videoconferencing platform. Similarly, pilot trainings aimed at Nigeria and Ethiopia were delivered remotely in January 2022 and July 2022, respectively. 34, 25, and 26 learners enrolled in the pilot trainings conducted in Eswatini, Nigeria, and Ethiopia, respectively.

Except for 2 out of 26 learners who participated in the pilot training for Ethiopia and did not complete the post-tests after completing the e-learning courses, all other participants successfully finished the training. We found that learners' scores on the post-tests were higher than on the pre-tests for both courses. Upon applying the Student's t-test to pre-test and post-test's results, a positive significant difference was found in Tanzania, Eswatini and Nigeria (Table 1). The *p*-value for the paired t-test for the difference in mean score on the pre-and post-test for each module was <0.001.

In the years following the implementation of the pilot trainings, multiple step-down training sessions were delivered in Tanzania, Eswatini, and Nigeria by 39 sub-tutors, including 17 in Tanzania, 14 in Eswatini and 8 in Nigeria, thus successfully implementing the second level of the program in these countries. Out of the 827 learners that were registered in Schoolroom by tutors, including 319 learners in Tanzania, 375 learners in Eswatini and 133 learners in Nigeria, 472 attended the step-down trainings. Of these, 421 learners (89%) successfully completed the training program, including 157 learners in Tanzania, 178 learners in Eswatini and 86 learners in Nigeria. It is worth noting that 37 learners in Nigeria completed only course 1 as they attended a shorter version of the training package that included only the first course. This decision was based on their professional background and qualifications, which did not relate to the management of anti-TB drugs. The remaining 49 learners did both the courses.

We found that learners' scores on the post-tests were higher than on the pre-tests for both courses. Upon applying the Student's t-test to pre-test and post-test's results, a positive significant difference was found in Tanzania, Eswatini and Nigeria (Table 2). Again, the *p*-value for the paired t-test for the difference in mean score on the pre- and post-test for each module was <0.001. Unlike the other three countries, Ethiopia could not implement the step-down trainings because of organizational hurdles.

Most of those who attended the pilot trainings in the four PAVIA countries completed the evaluation and the attitude questionnaires (Table 3). Specifically, 111 out of 121 learners (92%) who attended the pilot trainings provided feedback on the training program: 35 in

TABLE 1 Main features and results of the PAVIA pilot trainings conducted in the four PAVIA countries (e-learning course 1: "The Basic Concepts in Pharmacovigilance"; e-learning course 2: "An Overview of Tuberculosis and Anti-Tuberculosis Drug Safety Issues, Monitoring and Management (aDSM)").

PAVIA country	N. of learners registered in Schoolroom	N. of learners who attended the pilot training and successfully completed the training program (%)	Time period	N. of days	Program structure	Post-test vs. pre-test Student's *t* test score
Tanzania	36	36	October 2019	5	Face-to-face and online e-learning sessions*	E-learning course 1: 13.32 ($p < 0.00001$)
						E-learning course 2: 11.59 ($p < 0.00001$)
Eswatini	34	34	April 2021	4	Virtual sessions and online e-learning sessions	E-learning course 1: 7.91 ($p < 0.00001$)
						E-learning course 2: 10.77 ($p < 0.00001$)
Nigeria	25	25	January 2022	4	Virtual sessions and online e-learning sessions	E-learning course 1: 5.03 ($p < 0.00001$)
						E-learning course 2: 9.02 ($p < 0.00001$)
Ethiopia	26	26	July 2022	4	Virtual sessions and online e-learning sessions	E-learning course 1: 4.96 ($p < 0.00001$)
						E-learning course 2: 7.93 ($p < 0.00001$)
Total	121	121 (100%)	-	-	-	-

TABLE 2 Main features and results of the PAVIA step-down trainings conducted in Tanzania, Eswatini and Nigeria (e-learning course 1: "The Basic Concepts in Pharmacovigilance"; e-learning course 2: "An Overview of Tuberculosis and Anti-Tuberculosis Drug Safety Issues, Monitoring and Management (aDSM)").

PAVIA country (N. of sub-tutors)	N. of learners registered in Schoolroom	N. of learners who attended the step-down trainings (%)	N. of learners who successfully completed the training program on the number of attendees (%)	Post-test vs. pre-test Student's *t* test score
Tanzania (17)	319	175 (55%)	157 (90%)	E-learning course 1: 16.30 ($p < 0.00001$)
				E-learning course 2: 16.77 ($p < 0.00001$)
Eswatini (14)	375	200 (53%)	178 (% 89%)	E-learning course 1: 7.37 ($p < 0.00001$)
				E-learning course 2: 9.51 ($p < 0.00001$)
Nigeria (8)	133	97 (73%)	86* (%89%)	E-learning course 1: 13.01 ($p < 0.00001$)
				E-learning course 2: 9.65 ($p < 0.00001$)
Total	827	472 (57)	421 (89%°°)	-

*37/86 learners who attended the step-down trainings in Nigeria only did course 1 as they undertook a shorter version of the training package that included only the first course due the fact that their professional background and professional qualification did not related to the management of anti-TB drugs.

TABLE 3 Distribution of respondents providing feedback via evaluation and attitude questionnaires.

PAVIA country	Evaluation questionnaire		Attitude questionnaire	
	N. of respondents/N. of learners who completed the training (%)		N. of respondents/N. of learners who completed the training (%)	
	Pilot training	Step-down trainings	Pilot training	Step-down trainings
Tanzania	35/36 (97%)	44/157 (28%)	36/36 (100%)	34/157 (22%)
Eswatini	34/34 (100%)	9/178 (5%)	31/34 (91%)	12/178 (7%)
Nigeria	22/25 (88%)	63/86 (73%)	22/25 (88%)	59/86 (69%)
Ethiopia	20/26 (77%)	-	22/26 (85%)	-
Total	111/121 (92%)	116/421 (28%)	111/121 (92%)	105/421 (25%)

TABLE 4 Summary of key findings from evaluation and attitude questionnaires.

PAVIA country	High satisfaction with PAVIA training program		Reliable Internet connectivity during the training		Improved perception of pharmacovigilance after the training		Willingness to report at least an ADR after the training	
	N. of positive responses/ Total respondents (% of positive responses)		N. of positive responses/ Total respondents (% of positive responses)		N. of positive responses/ Total respondents (% of positive responses)		N. of positive responses/ Total respondents (% of positive responses)	
	Pilot training	Step-down trainings	Pilot training	Step-down trainings	Pilot training	Step-down trainings	Pilot training	Step-down trainings
Tanzania	32/35 (91%)	41/44 (93%)	24/35 (69%)	36/44 (82%)	36/36 (100%)	32/34 (94%)	28/36 (78%)	19/34 (56%)
Eswatini	34/34 (100%)	8/9 (89%)	30/34 (88%)	7/9 (78%)	30/31 (97%)	12/12 (100%)	30/31 (97%)	12/12 (100%)
Nigeria	22/22 (100%)	63/63 (100%)	19/22 (86%)	60/63 (95%)	22/22 (100%)	59/59 (100%)	22/22 (100%)	57/59 (97%)
Ethiopia	19/20 (95%)	-	20/20 (100%)	-	22/22 (100%)	-	22/26 (85%)	-
Total	107/111 (96%)	112/116 (97%)	93/111 (84%)	103/116 (89%)	110/111 (99%)	103/105 (98%)	102/111 (92%)	88/105 (84%)

Tanzania (97%), 34 in Eswatini (100%), 22 in Nigeria (88%), and 20 in Ethiopia (77%). The overall feedback was positive, with 107 out of 111 respondents (96%) expressing satisfaction to strong satisfaction with the pilot training program. A majority of respondents, 93 out of 111 (84%), reported that Internet connection was at least available, albeit sometimes limited, during the training. 111 out of the 121 learners (92%) who attended the pilot trainings completed the attitude questionnaires. These included 36 out of 36 learners in Tanzania (100%), 31 out of 34 in Eswatini (91%), 22 out of 25 in Nigeria (88%), and 22 out of 26 in Ethiopia (85%). Remarkably, 110 out of 111 learners (99%) reported an improved perception of PV after the training, indicating a significant positive shift in their attitudes toward PV. The stark majority, as indicated by 102 out of 111 respondents (92%), stated that they had submitted or were willing to submit at least one ADR report to local PV centers after attending the training (Table 4).

Only 116 out of 421 learners (28%) who attended the step-down trainings provided feedback on the training program: 44 out of 157 in

TABLE 5 Number and features of ICSRs entered in VigiBase 12 months prior and after the pilot trainings in Tanzania, Eswatini and Nigeria.

	Tanzania		Eswatini		Nigeria	
	Pre-pilot training (% of vaccines-related ICSRs, % of COVID-19 vaccines-related ICSR)	Post-pilot training (% of vaccines-related ICSRs, % of COVID-19 vaccines-related ICSR)	Pre-pilot training (% of vaccines-related ICSRs, % of COVID-19 vaccines-related ICSR)	Post-pilot training (% of vaccines-related ICSRs, % of COVID-19 vaccines-related ICSR)	Pre-pilot training (% of vaccines-related ICSRs, % of COVID-19 vaccines-related ICSR)	Post-pilot training (% of vaccines-related ICSRs, % of COVID-19 vaccines-related ICSR)
Total n. of ICSRs	2,369 (0–0%)	14,512 (0–0%)	717 (0–0%)	1,222 (86–86%)	13,284 (70–67%)	15,986 (86–76%)
N. of ICSRs concerning serious ADRs (%)	315 (13%) (0–0%)	197 (1%) (0–0%)	124 (17%) (1–0%)	74 (6%) (66–66%)	1,675 (13%) (59–45%)	2,230 (14%) (72–40%)
N. of anti-TB drugs-related ICSRs (%)*	64 (3%)	142 (1%)	285 (40%)	67 (40%)	419 (11%)	175 (8%)
Most prolific reporters	Pharmacists (2,194)	Pharmacists (14,010)	Physicians (460)	Other HCPs (637)	Other HCPs (9,744)	Other HCPs (14,346)

*The percentage of ICSRs associated with anti-TB drugs was calculated based solely on the number of ICSRs linked to drug treatments.

Tanzania (28%), 9 out of 178 in Eswatini (5%), and 63 out of 86 in Nigeria (73%). Despite a response rate lower than the one recorded after the pilot trainings, 112 out of 116 respondents (97%) reported strong to very strong satisfaction with the step-down trainings. Respondents who said that Internet connection was available were 103 (89%). The number of those who attended the step-down trainings and completed the attitude questionnaire was 105 (25%), including 34 respondents in Tanzania (22%), 12 in Eswatini (7%) and 59 in Nigeria (69%). Of these, 103 (98%) said that they felt more involved in PV after attending the training. Moreover, 88 out of 105 respondents (84%) confirmed that they had submitted or were willing to submit at least one ADR report to local PV centers after the training (Table 4).

In order to assess the potential impact of the blended e-learning-based PAVIA strategy on the PAVIA countries spontaneous reporting systems, a qualitative analysis of the ICSRs entered in VigiBase by the National Pharmacovigilance Centres of three out of four PAVIA countries was performed (Table 5).

ICSRs entered into VigiBase by the National Pharmacovigilance Centre of Tanzania over a one-year period before the first PAVIA training, that is, from 25.10.2018 to 25.10.2019, and over a one-year period after it, from 25 October 2019 to 26 October 2020, were retrieved via VigiLyze. Data analysis revealed that 2,369 ICSRs were received before the training and 14,512 ICSRs were received after, marking a net increase of 12,143 reports (+513%). Of the 2,369 ICSRs received before the pilot training, 2,022 concerned non-serious ADRs, 315 concerned serious ADRs and 32 concerned ADRs of unknown seriousness. At that time, the most prolific reporters were pharmacists, who submitted 2,194 ICSRs.

Of the 14,512 ICSRs received after the pilot training, 14,315 concerned non-serious ADRs and 197 concerned serious ADRs. No ICSRs with ADRs of unknown seriousness were received. The most prolific reporters remained pharmacists, who submitted 14,010 ICSRs. While the absolute number of ICSRs associated with anti-TB drugs increased from 64 before the pilot training to 142 after the pilot training, the percentage of these reports relative to the total decreased from 35 to 1%. No ICSRs associated with vaccines were received before or after the training.

ICSRs entered into VigiBase by the National Pharmacovigilance Centre of Eswatini over a one-year period before the first PAVIA training, that is, from 29 April 2020 to 29 April 2021, and over a one-year period after it, from 30 April 2021 to 30 April 2022, were retrieved via VigiLyze. Data analysis revealed that 717 ICSRs were received before the training and 1,222 ICSRs were received after, marking an increase of 505 reports (+70%). Of the 717 ICSRs received before the pilot training, 593 concerned non-serious ADRs and 124 concerned serious ADRs. The most prolific reporters were physicians, who submitted 460 ICSRs.

Of the 1,222 ICSRs received after the pilot training, 1,148 concerned non-serious ADRs and 74 concerned serious ADRs. No ICSRs with ADRs of unknown seriousness were received. The most prolific reporters were other HCPs, who submitted 637 ICSRs. After the training, there was a significant decrease in the absolute number of ICSRs associated with anti-TB drugs, decreasing from 285 to 67, while the percentage remained unchanged at 40%. On the other hand, before the pilot training, there were hardly any reports related to vaccines. However, following the training, there was a significant increase in these reports, jumping from 0% to 86%. Notably, all the reported vaccines were for COVID-19.

ICSRs entered into VigiBase by the National Pharmacovigilance Centre of Nigeria over a one-year period before the first PAVIA training, that is, from 20 January 2021 to 20 January 2022, and over a one-year period after it, from 21 January 2022 to 21 January 2023, were retrieved via VigiLyze. Data analysis revealed that 13,284 ICSRs were received before and 15,986 ICSRs after the pilot training, marking a slight increase of 2,702 reports (+20%). Of the 13,284 ICSRs received before the pilot training, 11,609 concerned non-serious ADRs and 1,675 concerned serious ADRs. The most prolific reporters were other HCPs, who submitted 9,774 ICSRs.

Of the 15,986 ICSRs received after the pilot training, 13,756 concerned non-serious ADRs and 2,230 concerned serious ADRs. No ICSRs with ADRs of unknown seriousness were received. The most prolific reporters were other HCPs, who submitted 14,346 ICSRs. After the training, there was a significant decrease in both the absolute number and the percentage of ICSRs related to anti-TB drugs, dropping from 419 to 175 and from 115 to 8%, respectively. The proportion of ICSRs related to vaccines remained high both before the pilot training (70%) and after (86%). Moreover, the majority of these ICSRs consisted of COVID-19 vaccine reports, comprising 67% before the pilot training and 76% after the pilot training.

We did not assess the quality of ICSRs, as such an analysis would have necessitated a longer observation period.

Discussion

The present work represents an example of an innovative strategy specifically designed to strengthen PV in four African countries through a blended e-learning-based ToT program. As far as we know, even though some training on PV had been previously provided on the ground by the African partners, this was one of the first educational experience involving fully remote training on PV to be conducted between Italy and multiple African countries via a videoconferencing platform. We demonstrated the effectiveness and the adaptability of an innovative approach that brings together elements of the blended e-learning methodology, the ToT model, and the use of video conferencing tools to mentor HCPs in both PV and the safety of anti-TB drugs.

The implementation of the second level of our strategy was carried out by those learners who had been trained in the first stage of the program. Those newly trained tutors conducted multiple step-down trainings under the supervision of PAVIA local coordinators. Moreover, our team was able to monitor the progress of single individuals and entire classrooms and provided technical assistance at tutors' request. Out of the 827 learners registered by local tutors in Schoolroom to participate in the step-down trainings conducted in Tanzania, Nigeria, and Ethiopia, 421 (51%) completed the program and received certificates. One possible explanation for this outcome is that, after being registered on the e-platform by tutors, some learners were unable to attend due to various reasons such as lack of connectivity, difficulty accessing the training site, administrative hurdles like permissions and reimbursement issues, among other challenges. Out of 472 who enrolled in the step-down trainings, 421 (89%) completed the training program. The number of successful learners in Nigeria included those learners who attended a shorter version of the training program based on the sole completion of Course 1. Distance and blended e-learning approaches in the field of pharmacovigilance are not novel concepts. Several studies in the literature have underscored the effectiveness of blended e-learning programs in healthcare, including pharmacovigilance (19–24). For instance, Rudd et al. conducted an evaluation of a blended e-learning course in Namibia and Tanzania, concluding that this approach is an effective method for training healthcare workers in the fundamental features of electronic health information systems (19).

Unlike in the other three countries, no step-down trainings were conducted in Ethiopia due to unspecified organizational hurdles.

More than 90% of those who attended the pilot trainings in the four PAVIA countries completed and submitted both the evaluation and the attitude questionnaires. Learners that attended the pilot trainings were satisfied with the contents and structure of the courses and, in general, with how the blended e-learning program was implemented in each country. No significant difference in terms of appreciation between learners who attended the in-person sessions included into the pilot training for Tanzania and those who participated in the virtual sessions of the pilot trainings for Eswatini, Nigeria, and Ethiopia was observed.

Measuring satisfaction of those learners who attended the step-down trainings proved difficult, as most of them (73%) did not complete and submit the evaluation questionnaire. As in the case of evaluation questionnaires, attitude questionnaires were not submitted by most of these learners (75%), thus strongly limiting the assessment of learners' perception of PV after the training. While being low, the response rate is consistent with similar trends reported in the literature (28).

Still, in both cases the limited data that we managed to collect suggest that even those learners who attended step-down trainings were satisfied with the training experience and that their interest in PV increased after the training. In particular, a significant number of respondents submitted or were willing to submit at least an ADR report after the training. As new tutors were left free to set up trainings in accordance with their own, any possible feedback provided by learners might have been affected by the individual decisions taken by local tutors regarding the duration and the preferred mode of implementation of the training. Additionally, organizational hurdles related to the distribution of questionnaires to students could have impacted the reliability of these results. Future research should address these factors for a more comprehensive understanding.

Replacing the in-person sessions with virtual sessions was the most feasible way to overcome the challenge posed by the inability to travel abroad during the COVID-19 pandemic. We chose to use a well-known videoconferencing platform because of its widespread availability and usability. This turned out to be wise choice as the use of a free version of the platform allowed us to reach learners without incurring in major technical issues. Adopting virtual meetings as teaching tool came with both advantages and limitations.

This could be seen clearly during the implementation of the first pilot training program in Tanzania, which involved more in-person dialog, conversations and real time interaction between learners than the other pilot trainings. Learners seemed at ease in a familiar, traditional classroom setting without technological barriers. The in-person interaction facilitated a more personal connection with learners, enhancing the exchange of information. On the other hand, Kiguli-Malwadde et al., who assessed the impact of transitioning a multi-country HIV training program from in-person to online, compared digital training approaches implemented during the pandemic with in-person approaches used before COVID-19. Their study concluded that participants in in-person learning programs exhibited greater gains in knowledge and clinical confidence than those engaged in online learning (29).

In this training section, all participants were engaged and enthusiastic; they demonstrated a keen interest in learning the program and a strong desire to broaden their knowledge on the presented topics. Questions from the audience were precise and relevant. Notably, on day 4, participants exhibited remarkable effort when tasked to take on the role of "trainers." The inclusion of a 'pharmacovigilance comedy' played a pivotal role at the session's conclusion, proving to be a success as participants interpreted it with the right spirit.

At the same time, relying on remote sessions to reach out to learners during COVID-19 pandemic demonstrated that, while the lack of face-to-face contact made difficult to interact with learners sometimes, it cut costs and time. Rudd et al. evaluated a blended e-learning course in Namibia and Tanzania reported that the cost is up to 3.4 times less expensive than for an in-person course with similar content (19). In addition, remote sessions allowed tutors from those PAVIA countries where the training program was at a more advanced stage to attend the trainings and share their own experience with conducting step-down trainings in their own country. This was

strongly appreciated by learners, who had the opportunity to listen to and benefit from the experience of those who had already conducted second-level trainings in their own countries. The learning environment was responsive and engaging and attention level was always very high among the participants during all 3 days without any distraction. The greatest limitation of virtual meetings came from the poor Internet connectivity, which might have negatively impacted the learning experience sometimes. Although neither we nor learners experienced any meaningful technical issues during the virtual sessions, Internet connection was not always stable throughout the meetings, as many learners who attended different sessions reported in the evaluation questionnaire.

The lack of good connection or even Internet access might pose a significant challenge not only for tutors that choose to replace in person sessions with virtual meetings but also for those learners who live and work in remote areas of the countries of interest, who might find themselves unable to access the e-learning materials. To bypass this issue, we provided the newly appointed tutors of each PAVIA country with USB flash drives containing an offline version of the courses. These USB flash drives were effectively used in Tanzania, Eswatini and Nigeria to assist those learners who struggled to access the online contents because of poor connectivity.

The implementation of the PAVIA training program in multiple settings, though under similar conditions, offered an opportunity to test the functioning of Schoolroom, our e-learning platform. While most of learners used a computer rather than a smartphone to access Schoolroom, no significant technical issues were reported by both groups. This strongly argues in favor of the versatility of the platform and suggests that relying on a software that is both a desktop and a mobile-friendly platform might allow a widespread access to e-learning contents in settings where smartphones represent the most used device. Overall, Schoolroom was seen as a user-friendly, well-performing platform which most of learners were able to access to and navigate through.

Assessing the real impact of the pilot trainings on the spontaneous reporting systems of Tanzania, Eswatini, and Nigeria was not an easy task as we could not match reporters to learners who attended the trainings. In the year after the pilot trainings a net increase in the number of ICSRs entered into VigiBase by the national pharmacovigilance centers was observed in three countries out of four PAVIA countries, suggesting that training actually had a positive effect on reporting rate. With more than 14,000 ICSRs entered in the year following the pilot training, Tanzania was the country that registered the highest increase. Importantly, the increase in the number of ICSRs observed in Tanzania was not driven by reporting of vaccines-related ADRs.

Pharmacists submitted the highest number of both pre-training ICSRs and post-training ICSRs, persisting as the most active reporters in the country. The increase in the number of ICSRs followed a slightly different pattern in Eswatini and Nigeria, as it appeared to be much more limited Additionally, in both countries this increase in reporting rate was connected to active surveillance of COVID-19 vaccines, which were widely deployed in both countries in the last 2 years. The development and distribution of COVID-19 vaccines in 2020 and 2021, respectively, align with the observed trend in vaccination in these nations. The high number of COVID-19 vaccines-related ICSRs entered into VigiBase over the past few years made hard to tell for sure whether those numbers could be ascribed to spontaneous reporting or rather depended on the close monitoring of the safety of COVID-19 vaccines.

The percentage of ICSRs related serious ADRs decreased in the year following the pilot training in all countries except Nigeria, where a constant trend was observed. Numerous factors could have influenced the reporting trends, particularly with the emergence of the COVID-19 pandemic in 2020, which led to considerable disruptions in the health and pharmacovigilance systems of these countries. After the pilot training, Tanzania experienced a substantial increase in the total number of ICSRs, which might have contributed to a decrease in the proportion of serious ICSRs. Eswatini was the country most influenced by the COVID-19 vaccination trend in reporting, as our training took place in April 2021. The potential reason for the decrease of serious ICSRs in Eswatini could be attributed to the increase in non-serious ICSRs, mainly due to COVID-19 vaccine reports, resulting in a decreased proportion of ICSRs concerning serious ADRs. In other countries, a similar trend emerged. The Italian Medicines Agency released a report on COVID-19 vaccine safety, covering the initial 2 years of vaccine surveillance. The vast majority of vaccine-related ICSRs logged in the Italian pharmacovigilance database during this period were associated with non-serious events.

In Nigeria, we observed a consistent trend, where the influence of COVID-19 vaccination on reporting remained steady both before and after our training.

Considering this, incorporating an intermediate evaluation, such as 6 months after the intervention, could have provided a more comprehensive assessment of the data.

Across the three PAVIA countries, the analysis of ICSRs related to anti-TB drugs shows divergent trends. In Tanzania, there was an increase in the absolute number of those ICSRs, accompanied by a decrease in the percentage. In Eswatini, the absolute number decreased, while the percentage remained constant. Conversely, in Nigeria, both the absolute number and the percentage decreased. Due to the limited number of ICSRs associated with anti-TB drugs, it is difficult to provide a unified explanation for all PAVIA countries. In summary, we have designed and successfully implemented an innovative, blended e-learning program in the four PAVIA countries to train an extensive number of HCPs in both the basic principles of PV and the safety of anti-TB drugs. Over a span of more than 3 years, dedicated groups of newly-formed trainers conducted multiple step-down trainings in three of the four countries, training hundreds of HCPs and contributing to foster a culture of PV and spontaneous reporting in each country. Analysis of pre-test and post-test scores revealed that our e-learning courses effectively improved learners' knowledge on the targeted topics, as significant learning progress was consistently observed following each training session. Overall, learners' feedback on the training experience was positive, with most of them expressing satisfaction with the training and an increased interest in pharmacovigilance after their participation. The utilization of virtual sessions did not appear to affect learning outcomes, as there were any major differences between those learners who attended in-person sessions during the pilot training in Tanzania and those who received remote training. While remote training may have limited interaction between trainers and learners, it provided a vital avenue to reach a broader audience at

a time when international travel was severely restricted due to the COVID-19 pandemic, making in-person training nearly impossible. To sum up, our experience shows that, despite its limitations, remote learning represents a versatile, cost-effective alternative to in person training and should be taken in consideration when planning for training in distant or less accessible areas. Schoolroom, our e-learning platform, performed well. No major technical issue arose during the trainings apart from poor connectivity. This was addressed by using USB flash drives and our platform, which could operate both online and offline. Similar projects should consider connectivity issues as a key factor. In conclusion, even when external conditions required us to conduct the training programs exclusively online in Eswatini, Nigeria, and Ethiopia, the system proved to be effective, yielding results comparable to those achieved through traditional methods. Finally, it is important to note that, while the trainings and other PAVIA initiatives might have had an impact on reporting rates in Tanzania, Eswatini, and Nigeria, a direct causal relationship between the trainings and the significant increase in ICSRs during the year following the pilot trainings could not be definitively established. This limitation arose because we were unable to match reporters to learners who attended the trainings. Additionally, it is crucial to acknowledge that the active surveillance of COVID-19 vaccines played a significant role in the observed upswing in the reporting rate.

Author's note

The information presented in this publication is sourced from VigiBase, the WHO global database of suspected adverse reactions to medicinal products, developed and maintained by Uppsala Monitoring Centre. It is important to note that the VigiBase data originates from various sources, and the likelihood of a suspected adverse effect being drug-related may vary across cases. Furthermore, the opinions expressed herein do not reflect those of the Uppsala Monitoring Centre or the World Health Organization.

Data availability statement

The dataset is not available due to the fact that it contains participants identifiable data that cannot be made public.

Author contributions

FS: Conceptualization, Writing – original draft, Writing – review & editing. KM: Writing – review & editing. SK: Writing – review & editing. EM: Writing – review & editing. AD: Writing – review & editing. SN: Writing – review & editing. CE: Writing – review & editing. AA: Writing – review & editing. SM: Writing – review & editing. SP: Data curation, Writing – review & editing. RL: Methodology, Software, Writing – review & editing. AS: Methodology, Software, Writing – review & editing. FC: Project administration, Writing – review & editing. LH: Project administration, Writing – review & editing. EE: Writing – review & editing. AC: Writing – review & editing. MV: Conceptualization, Supervision, Writing – review & editing. LM: Conceptualization, Supervision, Writing – review & editing. UM: Writing – review & editing, Conceptualization, Supervision.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This publication was produced by the PAVIA project. This project is part of the EDCTP2 program supported by the European Union (grant number CSA2016S-1627—PAVIA).

Acknowledgments

The authors want to express their deepest gratitude to all the people who participated in the PAVIA Project for their unwavering dedication and collaborative efforts, without which this publication would not have been possible.

Conflict of interest

EM was employed by KNCV Tuberculosis Foundation, Dar es Salaam, Tanzania. AD was employed by Baylor College of Medicine Children's Foundation-Eswatini. CE was employed by KNCV Tuberculosis Foundation, Abuja, Nigeria.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Author disclaimer

The views and opinions of authors expressed herein do not necessarily state or reflect those of EDCTP.

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2024.1347317/full#supplementary-material

References

1. World Health Organization. Roadmap for access to medicines, vaccines and health product 2019-2023: comprehensive support for access to medicines, vaccines and other health products [internet]. Geneva: World Health Organization; (2019) p. 57. Available at: https://iris.who.int/handle/10665/330145

2. Olsson S, Pal SN, Dodoo A. Pharmacovigilance in resource-limited countries. *Expert Rev Clin Pharmacol*. (2015) 8:449–60. doi: 10.1586/17512433.2015.1053391

3. Jones J, Mudaly V, Voget J, Naledi T, Maartens G, Cohen K. Adverse drug reactions in south African patients receiving bedaquiline-containing tuberculosis treatment: an evaluation of spontaneously reported cases. *BMC Infect Dis*. (2019) 19:544. doi: 10.1186/s12879-019-4197-7

4. Lyakurwa D, Lyimo J, Mleoh L, Riziki K, Lupinda M, Mpondo BC. Successful treatment of XDR-TB patient in Tanzania: report of the first XDR-TB patient. *Trop Dr*. (2019) 49:224–6. doi: 10.1177/0049475519833554

5. World Health Organization. *The use of Delamanid in the treatment of multidrug-resistant tuberculosis: Interim policy guidance*. Geneva: World Health Organization (2014).

6. World Health Organization. *Global tuberculosis report 2019*. Geneva: World Health Organization (2019).

7. Oelofse S, Esmail A, Diacon AH, Conradie F, Olayanju O, Ngubane N, et al. Pretomanid with bedaquiline and linezolid for drug-resistant TB: a comparison of prospective cohorts. *Int J Tuberc Lung Dis*. (2021) 25:453–60. doi: 10.5588/ijtld.21.0035

8. TB Alliance. Access to the BPaL Regimen. (2021). Available at: https://www.tballiance.org/access/countries (Accessed 27 November 2023).

9. Schick A, Miller KL, Lanthier M, Dal Pan G, Nardinelli C. Evaluation of pre-marketing factors to predict post-marketing boxed warnings and safety withdrawals. *Drug Saf*. (2017) 40:497–503. doi: 10.1007/s40264-017-0526-1

10. Alomar M, Tawfiq AM, Hassan N, Palaian S. Post marketing surveillance of suspected adverse drug reactions through spontaneous reporting: current status, challenges and the future. *Ther Adv Drug Saf*. (2020) 11:204209862093859. doi: 10.1177/2042098620938595

11. Isah AO, Pal SN, Olsson S, Dodoo A, Bencheikh RS. Specific features of medicines safety and pharmacovigilance in Africa. *Therapeut Adv Drug Saf*. (2012) 3:25–34. doi: 10.1177/2042098611425695

12. Strengthening Pharmaceutical Systems. Safety of medicine in sub-Saharan Africa: assessment of pharmacovigilance systems and their performance. In: *Submitted to the US Agency for international development by the strengthening pharmaceutical systems (SPS) program*. Arlington, VA: Management Sciences for Health, (2011).

13. Olsson S, Pal SN, Stergachis A, Couper M. Pharmacovigilance activities in 55 low- and middle-income countries: a questionnaire-based analysis. *Drug Saf*. (2010) 33:689–703. doi: 10.2165/11536390-000000000-00000

14. Barry A, Olsson S, Minzi O, Bienvenu E, Makonnen E, Kamuhabwa A, et al. Comparative assessment of the National Pharmacovigilance Systems in East Africa: Ethiopia, Kenya. *Rwanda Tanzania Drug Saf*. (2020) 43:339–50. doi: 10.1007/s40264-019-00898-z

15. Tiemersma EW, Ali I, Alemu A, Avong YK, Duga A, Elagbaje C, et al. Baseline assessment of pharmacovigilance activities in four sub-Saharan African countries: a perspective on tuberculosis. *BMC Health Serv Res*. (2021) 21:1062. doi: 10.1186/s12913-021-07043-6

16. Barteit S, Jahn A, Banda SS, Bärnighausen T, Bowa A, Chileshe G, et al. E-learning for medical education in sub-Saharan Africa and low-resource settings: viewpoint. *J Med Internet Res*. (2019) 21:e12449. doi: 10.2196/12449

17. Ruiz JG, Mintzer MJ, Leipzig RM. The impact of E-learning in medical education. *Acad Med*. (2006) 81:207–12. doi: 10.1097/00001888-200603000-00002

18. Muro E, Institute KMwamwitwa K, Kisenge S, Shiletiwa N, Moretti U, et al. Assessment of educational intervention impact on improving pharmacovigilance knowledge among health care providers: a study from different hospitals in Tanzania. *J Pharmacovigil Drug Res*. (2023) 4:18–24. doi: 10.53411/jpadr.2023.4.3.4

19. Rudd KE, Puttkammer N, Antilla J, Richards J, Heffron M, Tolentino H, et al. Building workforce capacity for effective use of health information systems: evaluation of a blended eLearning course in Namibia and Tanzania. *Int J Med Inform*. (2019) 131:103945. doi: 10.1016/j.ijmedinf.2019.08.005

20. Manyazewal T, Marinucci F, Belay G, Tesfaye A, Kebede A, Tadesse Y, et al. Implementation and evaluation of a blended learning course on tuberculosis for front-line health care professionals. *Am J Clin Pathol*. (2017) 147:285–91. doi: 10.1093/ajcp/aqx002

21. Rowe AK, Rowe SY, Peters DH, Holloway KA, Chalker J, Ross-Degnan D. Effectiveness of strategies to improve health-care provider practices in low-income and middle-income countries: a systematic review. *Lancet Glob Health*. (2018) 6:e1163–75. doi: 10.1016/S2214-109X(18)30398-X

22. Leslie HH, Gage A, Nsona H, Hirschhorn LR, Kruk ME. Training and supervision did not meaningfully improve quality of care for pregnant women or sick children in sub-Saharan Africa. *Health Aff*. (2016) 35:1716–24. doi: 10.1377/hlthaff.2016.0261

23. Ridde V. Per diems undermine health interventions, systems and research in Africa: burying our heads in the sand. *Trop Med Int Health*. (2010) 15:E1–4. doi: 10.1111/tmi.2607

24. Millimouno T, Alexandre D, Kolié J, Roegiers S, Garcia M, Kiyan C, et al. Outcomes of blended learning for capacity strengthening of health professionals in Guinea. *BMC Med Educ*. (2021) 21:406. doi: 10.1186/s12909-021-02847-w

25. Mormina M, Pinder S. A conceptual framework for training of trainers (ToT) interventions in global health. *Glob Health*. (2018) 14:100. doi: 10.1186/s12992-018-0420-3

26. Makanjuola V, Doku V, Jenkins R, Gureje O. Monitoring and evaluation of the activities of trainees in the 'training of trainers' workshop at Ibadan, south-West Nigeria. *Ment Health Fam Med*. (2012) 9:25–32.

27. Centre UM. Your window to a world of global safety insights. (2023). Available at: https://who-umc.org/pv-products/vigilyze/

28. Hegerius A, Caduff-Janosa P, Savage R, Ellenius J. E-learning in pharmacovigilance: an evaluation of microlearning-based modules developed by Uppsala monitoring Centre. *Drug Saf*. (2020) 43:1171–80. doi: 10.1007/s40264-020-00981-w

29. Kiguli-Malwadde E, Forster M, Eliaz A, Celentano J, Chilembe E, Couper ID, et al. Comparing in-person, blended and virtual training interventions; a real-world evaluation of HIV capacity building programs in 16 countries in sub-Saharan Africa. *PLOS Glob Public Health*. (2023) 3:e0001654. doi: 10.1371/journal.pgph.0001654

frontiers | Frontiers in Medicine

TYPE Original Research
PUBLISHED 18 April 2024
DOI 10.3389/fmed.2024.1375982

OPEN ACCESS

EDITED BY
Muhammad Azeem Ashraf,
Hunan University, China

REVIEWED BY
Rebecca S. Koszalinski,
Florida Atlantic University, United States
Musarrat Maisha Reza,
University of Exeter, United Kingdom

*CORRESPONDENCE
Noor Akmal Shareela Ismail
✉ nasismail@ukm.edu.my

RECEIVED 24 January 2024
ACCEPTED 26 March 2024
PUBLISHED 18 April 2024

CITATION
Ismail NAS, Mageswaran N, Bujang SM and Awang Besar MN (2024) Beyond words: analyzing non-verbal communication techniques in a medical communication skills course via synchronous online platform. *Front. Med.* 11:1375982. doi: 10.3389/fmed.2024.1375982

Beyond words: analyzing non-verbal communication techniques in a medical communication skills course via synchronous online platform

Noor Akmal Shareela Ismail[1]*, Nanthini Mageswaran[1], Siti Mariam Bujang[2] and Mohd Nasri Awang Besar[2]

[1]Department of Biochemistry, Faculty of Medicine, Universiti Kebangsaan Malaysia, Kuala Lumpur, Malaysia, [2]Department of Medical Education, Faculty of Medicine, Universiti Kebangsaan Malaysia, Kuala Lumpur, Malaysia

Background: Effective doctor-patient relationships hinge on robust communication skills, with non-verbal communication techniques (NVC) often overlooked, particularly in online synchronous interactions. This study delves into the exploration of NVC types during online feedback sessions for communication skill activities in a medical education module.

Methods: A cohort of 100 first-year medical students and 10 lecturers at the Faculty of Medicine, Universiti Kebangsaan Malaysia (UKM), engaged in communication skills activities via Microsoft Teams. Sessions were recorded, and lecturer NVC, encompassing body position, facial expressions, voice intonation, body movements, eye contact, and paralinguistics, were meticulously observed. Following these sessions, students provided reflective writings highlighting their perceptions of the feedback, specifically focusing on observed NVC.

Results: The study identified consistent non-verbal communication patterns during feedback sessions. Lecturers predominantly leaned forward and toward the camera, maintained direct eye contact, and exhibited dynamic voice intonation. They frequently engaged in tactile gestures and paused to formulate thoughts, often accompanied by filler sounds like "um" and "okay." This consistency suggests proficient use of NVC in providing synchronous online feedback. Less observed NVC included body touching and certain paralinguistic cues like long sighs. Initial student apprehension, rooted in feelings of poor performance during activities, transformed positively upon observing the lecturer's facial expressions and cheerful intonation. This transformation fostered an open reception of feedback, motivating students to address communication skill deficiencies. Additionally, students expressed a preference for comfortable learning environments to alleviate uncertainties during feedback reception. Potential contrivances in non-verbal communication (NVC) due to lecturer awareness of being recorded, a small sample size of 10 lecturers limiting generalizability, a focus solely on preclinical lecturers, and the need for future research to address these constraints and explore diverse educational contexts.

Conclusion: Medical schools globally should prioritize integrating NVC training into their curricula to equip students with essential communication skills for diverse healthcare settings. The study's findings serve as a valuable reference for lecturers, emphasizing the importance of employing effective NVC during online feedback sessions. This is crucial as NVC, though occurring online synchronously, remains pivotal in conveying nuanced information. Additionally,

educators require ongoing professional development to enhance proficiency in utilizing NVC techniques in virtual learning environments. Potential research directions stemming from the study's findings include longitudinal investigations into the evolution of NVC patterns, comparative analyses across disciplines, cross-cultural examinations, interventions to improve NVC skills, exploration of technology's role in NVC enhancement, qualitative studies on student perceptions, and interdisciplinary collaborations to deepen understanding of NVC in virtual learning environments.

KEYWORDS

non-verbal communication, synchronous, feedback, online, medical students

1 Introduction

Communication skills are important in building personal and professional relationships. In medicine, it is the basis for the relationship between a medical doctor and a patient. There are two types of communication which are, verbal communication and non-verbal communication. Non-verbal communication (NVC) is an important aspect of communication in conveying messages and can emphasize verbal communication. Compared to verbal communication, the area of non-verbal communication has been poorly explored.

Non-verbal communication encompasses the conveyance of information through bodily signals, encompassing elements such as eye contact, facial expressions, gestures, and vocal cues (paralinguistics) (1). An instance of this could be the act of smiling upon meeting someone, which signifies traits such as friendliness, acceptance, and openness. The utilization of non-verbal communication is ubiquitous, operating in myriad contexts, often occurring unconsciously. Therefore, it is important to study non-verbal means of communication based on the observation and analysis of physical movements compared to verbal communication, or the use of language to transfer information through written text, spoken or sign language. Recent studies show that communication skills among medical students are lacking, especially in areas of NVC and empathy toward patients (2–4). Feedback can improve the NVC of medical students during the communication process, especially facial expressions, body movements, body posture, silent intervals, and laughter (3). This technique is more meaningful and effective than verbal communication because it conveys a more dominant message to an individual after receiving feedback (3). In the event of a conflict, the message conveyed through NVC will be stored in the memory longer than verbal messages (5). The significance of NVC in conflict resolution lies in its ability to convey emotions, intentions, and attitudes non-verbally, thereby influencing the dynamics of interpersonal interactions. In conflict situations, NVC cues such as facial expressions, gestures, and body language can play a crucial role in either escalating or de-escalating tensions, fostering empathy, understanding, and collaboration among conflicting parties (2). By recognizing and interpreting NVC signals, individuals can better navigate conflicts, facilitate effective communication, and work toward mutually beneficial resolutions (6).

Online observation of NVC poses several limitations compared to face-to-face interactions. The digital medium may distort or diminish certain non-verbal cues, making accurate interpretation challenging (2). Factors such as poor video quality, lagging audio, or limited camera angles may obscure important NVC signals, leading to misinterpretations or incomplete assessments (7). Online observation lacks the immediacy and intimacy of in-person interactions, potentially hindering rapport-building and emotional connection between participants (1). Moreover, the absence of physical proximity in virtual settings may limit the range and subtlety of non-verbal behaviors that can be observed and analyzed (7). Subsequently, online observation may be subject to biases inherent in the digital platform, such as selection bias in participant recruitment or observer bias in data interpretation, further complicating the validity and reliability of NVC research conducted online (8).

Therefore, this feedback process needs to be given special attention because it is often neglected in studies related to effective communication. Communication skill activities will be more appreciated if a person's behavior can be observed more closely in non-verbal terms (6). The era of COVID-19 has transformed learning communication skills online. This impacts the detection of non-verbal communication that can be observed online and how it affects the effectiveness of communication with patients. This is because when online teaching is conducted, the observation of NVC through synchronous online applications is limited, so it can cause misunderstandings and thus can result in less effective communication. Therefore, NVC should be given extra attention especially when communication is done online synchronously so that the information conveyed is clear and fulfils its purpose. The observation of non-verbal communication (NVC) is limited to the visual cues captured by camera imagery, typically focusing on the upper body, in contrast to the comprehensive interaction afforded by face-to-face encounters (6, 8, 9). The scarcity of research dedicated to NVC diminishes its recognition as a pivotal component of effective communication. Therefore, this study aims to explore the types of NVC by lecturers during feedback sessions through a synchronous online application.

2 Materials and methods

2.1 Study design

Qualitative methods with an observational research approach were used to explore the types of non-verbal communication (NVC) among lecturers in giving feedback and gaining acceptance of Year 1

medical students in getting feedback on the performance of their communication skills in the Professional and Personal Development module. This feedback was given by the lecturer to improve student's performance. This observational study is important to see the types of NVC that are given online synchronously. The feedback process was recorded through the Microsoft Teams application for student reference so that students can make self-reflection and use all the feedback given to improve their weaknesses during communication skill activities.

2.1.1 Observational studies

An observational study was chosen as a research method to see the types of feedback given by lecturers on student performance. It only required one researcher to view the video footage and this method is a thorough method of collecting, recording, and analyzing data. Through this study, deductive and inductive thematic data analysis (10) was used to answer the questions and objectives of this study. Observational research also provides a platform to add new criteria or types of NVC based on observations from one individual lecturer to another. All aspects of the researched material were explained through data analysis from the feedback recording.

2.1.2 Reflective writing

Reflective writing has become one of the components of continuous assessment in medical education. It is a practice to look back at a student's performance and has become the core of the concept of learning from experience (11). This method is practiced to improve a student's ability to develop critical thinking, analytics, and cognition (12). Self-reflection is important to see if any new perspective was learned and helps improve student progress in learning a skill. Reflective writing is an additional research tool that helps to explore the effect of feedback from lecturers and the acceptance of the feedback from the student's perspective and how it can be used to improve their performance in communication.

2.2 Validity and reliability

There are two challenges in observational studies that researchers need to see, namely validity and reliability. The selected sample must have characteristics of the population that is being studied so that the study can give a general statement/picture about a population (13). Observational studies have low validity, meaning that the findings cannot be generalized to other populations (14). It is also because there is no control group comparison. However, the reliability of this study was high because the study observer was the same person all data or input obtained from the small group discussion activity session was processed by the researcher and no case of bias or observer variation occurred. This study was conducted well as all respondents (students and lecturers) gave their full cooperation, instructions given to the participants were clear and the format of the study was systematic.

In this study, maintaining methodological consistency was paramount. Before data collection commenced, a team of three researchers convened to establish standardized observation protocols, guided by a predetermined checklist. To acquaint themselves with the protocol, a trial feedback session was conducted, serving as both a training and standardization exercise. A standardized evaluation method was then selected to ensure adherence to predefined non-verbal communication (NVC) criteria and maintain consistency across observations. Furthermore, the standard-setting process involved three independent researchers, who collectively established benchmarks for specific NVC types.

The observation process consisted of three rounds. Initially, individual marks were assigned during the first round of observation. Subsequently, collaborative discussions ensued during the second round to refine observations and address any discrepancies. Finally, a third round was conducted to collectively discuss and reach a consensus on the evaluation of each NVC parameter. To facilitate the inductive thematic analysis, specific keywords were established to describe different NVC types, streamlining the analysis process.

2.3 Study location

This study observed the types of non-verbal communication of lecturers on the performance of Year 1 medical students who undergo communication skill activities in the Professional and Personal Development module which is conducted online synchronously. The course content encompassed the demonstration of multiple soft skills and aspects of professionalism pertinent to university settings. These included proficiency in self-management and coping strategies, fostering a caring attitude and sensitivity toward both personal needs and those of significant others, adeptness in critical thinking and interpersonal communication for learning and everyday life scenarios, advocacy for healthy lifestyles while recognizing the implications of unhealthy behaviors, particularly within the context of medical student life, and extending these principles to the broader public. Additionally, the course also emphasized the cultivation of a team-oriented spirit of collaboration across diverse professions, underpinned by principles of integrity and passion. This study was conducted through the Microsoft Teams online application (15). All student activities and lecturer feedback were recorded for data analysis purposes.

2.4 Population of study and sampling

The population of this study consisted of Year 1 undergraduate medical students of UKM who are undergoing the Professional and Personal Development module (FFFF1813) in the 1st semester of the 2020/2021 session. This group of first-year students have never undergone any formal feedback session neither the Professional and Self-Development module. Purposive sampling was used and the participants for this study were selected according to the criteria set by the researcher. The inclusion criteria for this study were as follows: 1. First-year undergraduate medical students who have never undergone the Professional and Personal Development module; 2. Students who give written consent to participate in this study. The exclusion criteria were first-year undergraduate medical students who have undergone the Professional and Personal Development module (repeat students) and students from years other than the first year. Students who agreed to be participants were divided into groups of 10 people per group according to the session that had been set by the researchers. All communication skill activities and feedback sessions were recorded through the Microsoft Teams application. This activity

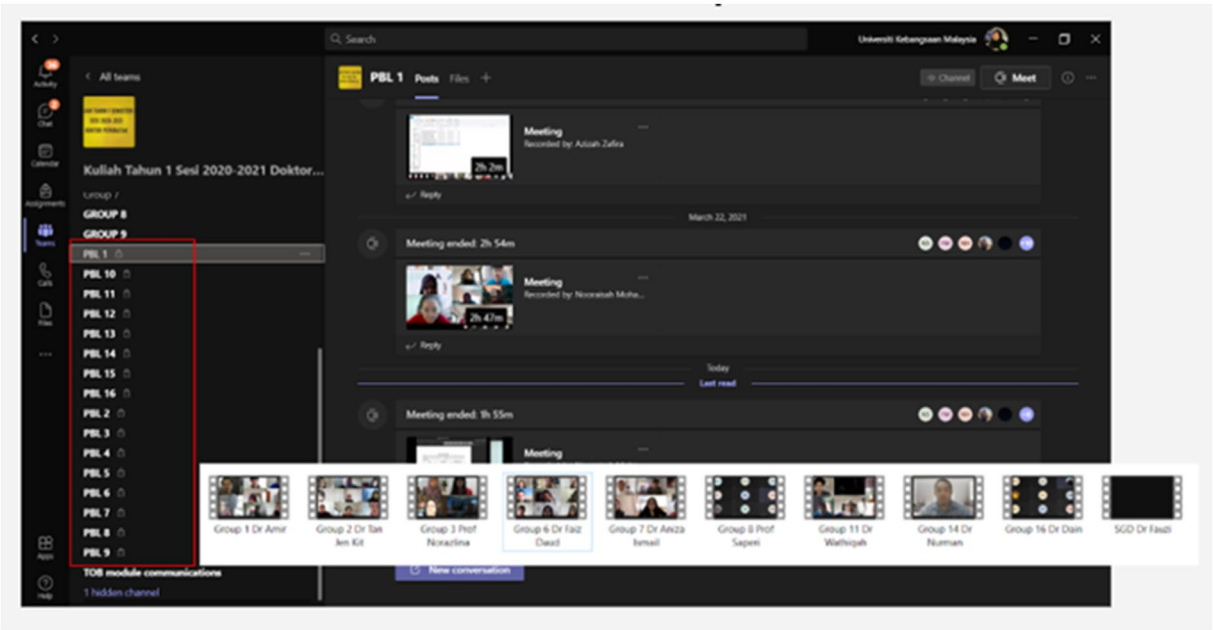


FIGURE 1
Communication skill activity conducted online synchronously and recorded via Microsoft Teams application.

was conducted for 2 h for each group. Then, a video recording of the feedback was given to each student. After the communication skill activity and feedback session from the lecturer, students wrote a reflection on the activity and how the feedback from the lecturer could be put into practice to improve their weaknesses during the activity.

2.5 Sample size

Researchers set 10 participants for each group and a total of 10 groups ($n = 100$) participated in this study. This is to facilitate the recording process that took place in a group and was recorded through the application in Microsoft Teams (Figure 1). Sample adequacy in qualitative inquiry refers to the evaluation of whether the sample's composition and size are suitable and relevant for the research objectives. This assessment plays a crucial role in determining the quality and trustworthiness of qualitative research. It involves ensuring that the chosen sample adequately represents the population of interest, possesses diversity where applicable, and is of a size sufficient to yield meaningful insights and achieve saturation, thereby enhancing the credibility and validity of the study findings (16). Since this was an observational study, the study sample did not need to be large, and the researcher had set observations in 10 different groups to reach conclusions for this study. For reflective writing, only two groups of study participants ($n = 20$) were required to do reflective writing about their performance through communication skill activities and acceptance of feedback given by their lecturer.

2.6 Data collection and analysis

Before the commencement of recordings, all participants received a comprehensive briefing. They were informed that the recordings would be utilized exclusively for research purposes and would be accessible solely to the researchers involved in the study (NASI, SMB, MNAB). Data taken during small group discussion activity was recorded using the Microsoft Teams online application. Then the video recording was viewed again. A checklist of types of non-verbal communication, such as body position, facial expressions, voice intonation, movement, eye contact and paralinguistics was created based on the observation of video recordings and literature studies (Supplementary Table 1). The process of verifying the types of non-verbal communication was done with two independent researchers who were not involved in the data collection process. This process was carried out by looking at 2 different types of videos. Three researchers (NI, SB, MB) marked the types of non-verbal communication and the time the behavior was observed. Then, these three researchers (NI, SB, MB) presented their observations and discussed the types of non-verbal communication observed. Next, NI, SB, and MB continued to observe the types of non-verbal communication until it reached a saturation level. This process is known as deductive thematic analysis (Figure 2) which was presented in a checklist (Supplementary Table 1).

For the analysis of the reflective writing, students were given the task of writing a reflection on their performance and the feedback given by the lecturer after the small group discussion. Reflective writings were collected according to the number of samples set ($n = 20$). A purposive sampling technique was used from two groups consisting of a young lecturer and a professor-ranked lecturer. Before the final analysis was obtained, the researcher marked similar themes and separated them according to main themes, sub-themes and statements involved (Supplementary Table 2). This process is known as inductive thematic analysis (Figure 3). This involves the process of repeating data, extracting data, assigning codes to sentences, forming themes, revisiting themes, determining and naming themes, and analyzing the study (17). Figure 4 shows the entire data collection

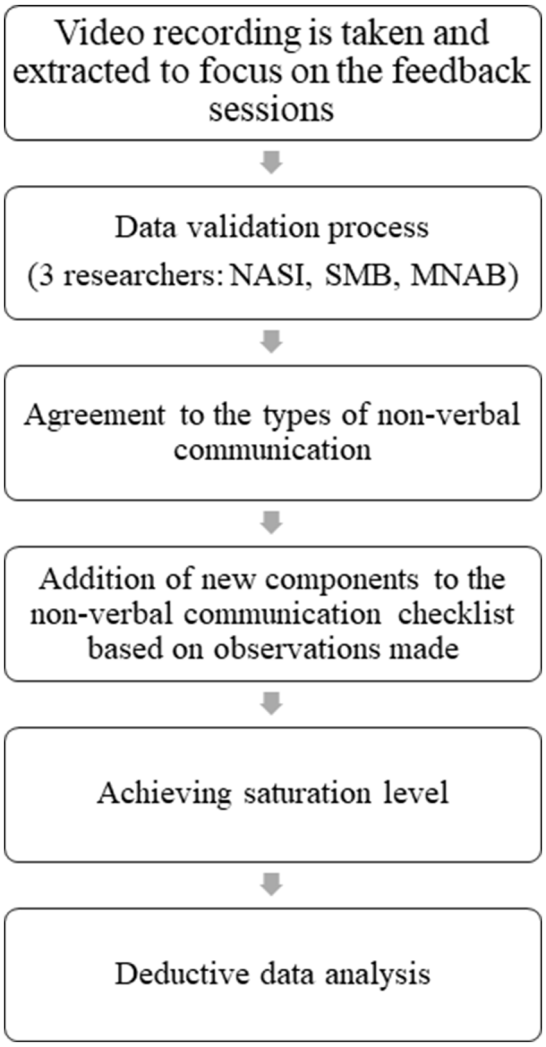


FIGURE 2
Deductive data analysis process in the observation of non- verbal communication via video recording.

process of this study. Confidentiality was maintained where only the researcher and the research team could access the information provided by study participants. Any name or personal identification was not used in this study and the information provided by the participants was recorded as K1P1 to refer to group 1 and the first participant, and so on.

3 Results

3.1 Types of non-verbal communication

Non-verbal communication encompasses the deliberate or involuntary behaviors exhibited by individuals during interpersonal interactions. In this study, feedback sessions were conducted within a tranquil environment, specifically designated personal rooms equipped with computers featuring cameras and microphones. This controlled setting aimed to minimize potential disruptions, such as interference from familial influences, thereby optimizing the focus and concentration of the subjects involved in the study. NVC can be seen through a person's body movements, eye contact and voice intonation. In this study, six types of NVC could be observed online, namely body position, facial expressions, voice intonation, movement, eye gaze and paralinguistics. For these types of NVC, a total of 10 lecturers were observed.

3.1.1 Body position

Body position only can be observed from chest level up to the head when captured online. Therefore, the observation is limited to the way the body is positioned toward the camera. Table 1a shows the percentage of lecturers who show the most dominant body position. This includes body leaning forward (100%), sitting upright (90%), bending over (0%), body position to the left (10%) and right. This shows that the most dominant body position exhibited by all lecturers was leaning forward and toward the camera. This shows that all the lecturers were very interested and worked hard to give feedback to the students. Throughout the feedback session, all the lecturers were seen sitting upright except for one lecturer who seemed to be sitting sideways to the left. This shows that the lecturers were always focused on delivering information to students.

3.1.2 Facial expressions

The lecturer's facial expressions are very important in conveying information and feedback to students. This is because the lecturer's facial expressions can be seen directly through the camera. Table 1b shows the description of the lecturer's facial expressions that were observed through the online application. These include looking directly into the camera (100%), smiling when speaking (100%), laughing (30%), frowning (10%), and raising eyebrows (20%). The most dominant facial expression was looking directly at the camera when giving feedback. This is important to show the lecturer's sensitivity and focus in delivering information. Some lecturers show cheerfulness by inserting jokes interspersed with laughter and smiles. This was to create a cheerful and comfortable atmosphere for students to receive feedback. However, some lecturers frowned and raised their eyebrows as the feedback session progressed. This shows a serious tone in conveying information.

3.1.3 Voice intonation

In addition to facial expressions, voice intonation also plays an important role in interaction with students. Cheerful voice intonation is essential in evoking a comfortable atmosphere in learning especially if it is done online. The observed types of voice intonation were monotonous, raising the voice, unclear and giving emphasis to a word (Table 1c). Through virtual observation, all lecturers had a dynamic and cheerful voice intonation. None had a monotonous or raised voice and was unclear throughout the conversation. There was a lecturer who always emphasized words. This was intended to attract students' attention to the information presented.

3.1.4 Movement

There were limitations in identifying the types of movements that can be recorded through the online application, including those related to touching the face, hand movements, and even the head. Table 1d shows the types of movements that were observed. The most dominant movements (50%) were hands touching the face, chin and nose and touching the glasses frame when giving feedback. This is

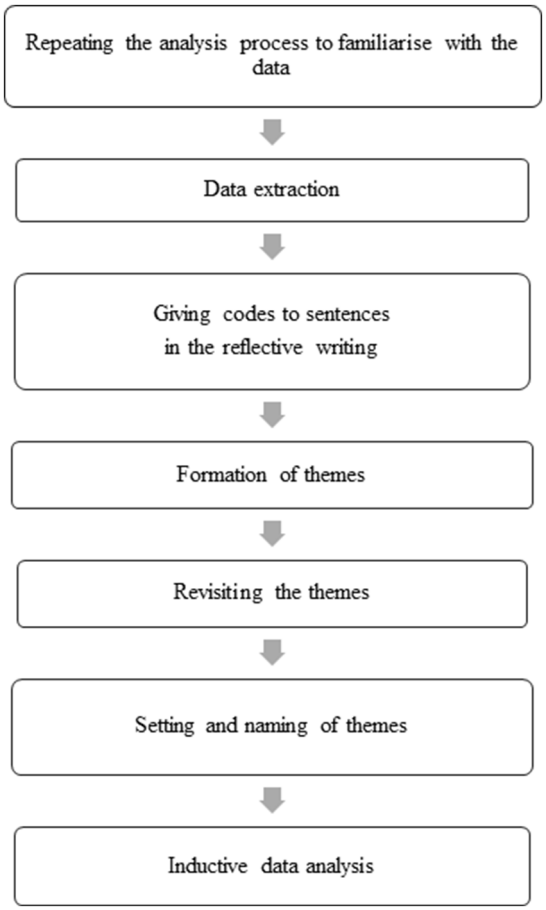


FIGURE 3
Inductive data analysis process of student acceptance of non-verbal communication of lectures through reflective writing.

followed by nodding, shaking the head, touching the hair, making free-hand movements, clapping and scratching behind the ears (20%). The least type of movement observed was body movement to the left/ right / front/back. This also includes scratching the body, scratching the forehead, squinting, rubbing the eyes, holding the shoulder, and giving the OK! sign (10%).

3.1.5 Eye contact

Eye contact is one of the types of non-verbal communication that is often observed in everyday communication. However, in online communication, this type of NVC is very meaningful, especially in conveying information. Therefore, lecturers must look toward the camera or computer screen when speaking. Overall, the most dominant eye contact was when 80% of lecturers looked to the left when giving feedback. This is followed by looking down (70%), to the right (60%) and up (30%; Table 1e).

3.1.6 Paralinguistics

Paralinguistics include types of non-verbal communication that involve sounds. This includes saying "aaah," "okay," "laaaah," "so," "hmmm..," surprised sounds, sighing sounds when complaining and clearing throat. Table 1f shows observations on the types of paralinguistics exhibited by lecturers. All lecturers seem to always pause to think of the best words in giving feedback to students (100%). This situation was filled with sounds like ...urmm/ "okay"/ lah/ "so"/"that's it" (100%). There was a lecturer who always cleared his throat when he paused for a moment (10%) and there was no observation of the sound of sighing or being surprised. The lecturers in this study were also not seen to speak too fast or too slowly (0%).

3.2 Student acceptance of non-verbal communication

After completing the communication skill activity, students were required to write a reflective essay expressing their feelings toward the lecturer's non-verbal communication. A total of two groups were selected in this study ($n = 20$). Each student's writing was extracted to form the same theme (Supplementary Table 2). An example of reflective writing is in Figure 5. The formation of subthemes from the same keywords was used to form the main theme. The findings of this study found 4 types of main themes, namely students' feelings before receiving feedback, while receiving feedback, after receiving feedback and the type of non-verbal communication that was observed. This write-up will be presented according to sub-themes and selected statements related to the keywords that make up the sub-themes and then the main theme.

3.3 Theme 1: students feelings before receiving feedback

At the beginning of the reflective writing paragraph, most students recorded their feelings before receiving feedback. This includes feelings of nervousness, restlessness, fear and apprehension.

3.3.1 Nervousness

The feeling of nervousness in the context of this study can be defined as a feeling of unease. Students have stated that they felt nervous before receiving feedback from the lecturer. This is because they were not confident in their performance in the communication skill activities. This was seen through examples of writing below:

> *"I felt very nervous and worried about the feedback of the facilitator and my other friends on my task"* (K2P1).

> *"I was worried and nervous because I thought our acting in the video was quite awkward since we did it* via *Zoom but not face to face"* (K2P3).

3.3.2 Restlessness

Feeling restless is different from feeling nervous. Students wrote down their feelings of anxiety before the feedback session. This is because they had palpitations during the face-to-face feedback session, even if it was conducted online. Examples of students' writing were as follows:

> *"I was already feeling anxious about what would be the feedback towards the outcome"* (K1P5).

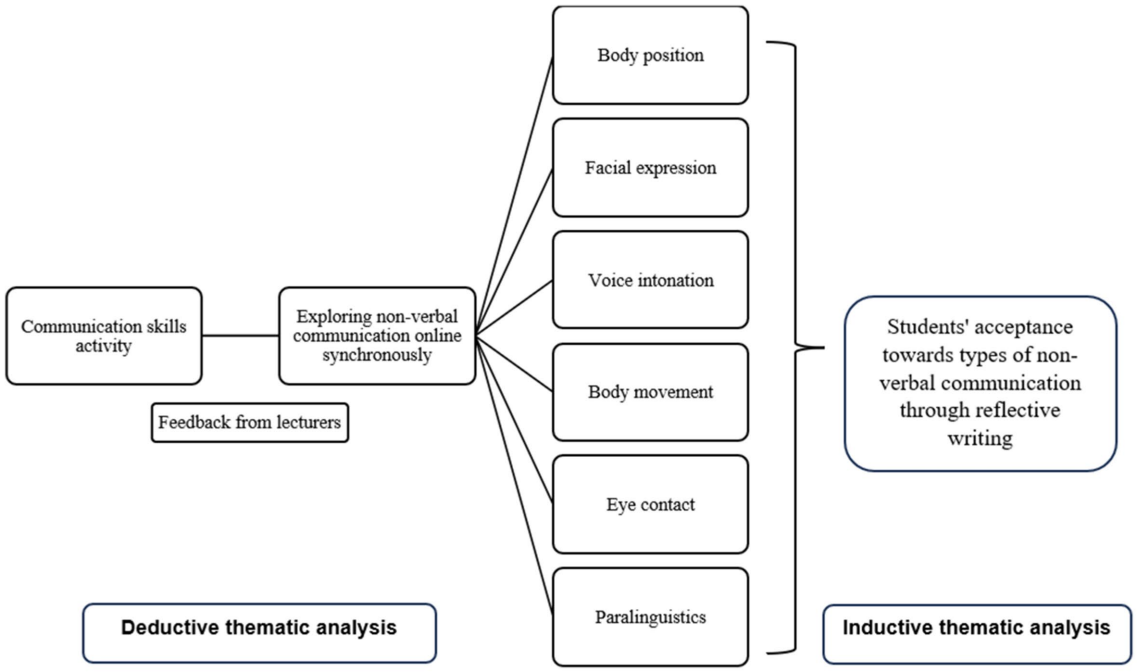


FIGURE 4
Flow chart of the data collection process.

> *"I felt really anxious and scared of what my friends and my facilitators would comment on my performance"* (K1P6).
>
> *"I was anxious and curious about how my teammates and our facilitator's opinions on the task"* (K1P3).
>
> *"I was worried and nervous for this session because I was scared that I would be the worst student for this task."* (K1P1).

3.3.3 Fear

Fear was also expressed by students in this reflective writing. The term fear can be defined as someone who feels worried (doubt, apprehensive), and is often associated with a feeling of anxiety. It can be seen in the student's writing below:

> *"I was worried and nervous for this session because I was scared that I would be the worst student for this task."* (K1P1).
>
> *"I was kind of scared as this was our first roleplay video"* (K2P2).
>
> *"We all still feel anxious, scared, and worried when receiving feedback as we are worried about how the facilitator looks at us and perceives us"* (K2P4).

3.3.4 Apprehension

In addition to fear, students also felt apprehensive before receiving feedback from their lecturer. This is because they were worried about their performance in the communication skill activities. The word apprehensive is interpreted as when a person is somewhat anxious or afraid of something happening, feels restless or uneasy (because of thinking about something), and worries about something. This can be seen in the statements below:

> *"I was not confident whether my performance was good enough to be accepted."* (K1P1).
>
> *"I felt a little bad about myself as I could not give a proper presentation"* (K1P2).
>
> *"Many things were running through my head thinking if there were parts that I could have done in a better way, after looking at some of my peer's performance"* (K1P9).
>
> *"I think I'm not good at communication and need some improvement"* (K1P10).
>
> *"I thought our acting in the video was quite awkward since we did it* via *Zoom but not face to face."* (K2P3).

TABLE 1 Types of non-verbal communication observed during the feedback session.

Types of non-verbal communication observed	Percentage (%)
a. Body position	
Leaning forwards	100
Sitting upright	90
Bending over	0
Body to the left side	10
Body to the right side	0
b. Facial expression	
Looking directly into the camera	100
Smiling	100
Laughing	30
Frowning	10
Raising eyebrows	20
c. Voice intonation	
Dynamic and cheerful voice	100
Monotonous	0
Raising voice	0
Unclear voice	0
Emphasizing words	10
d. Movements	
Hands touching face	50
Hands touching chin	50
Hands touching nose	50
Hands at the mouth	50
Nodding the head	20
Shaking the head	20
Body swaying to the left/right	10
Body swaying to the front/back	10
Free movement of hand	20
Hands on the hair	20
Scratching the body	10
Scratching the forehead	10
Squinting eyes	10
Rubbing eyes	10
Touching shoulders	10
Touching frame of glasses	50
Clapping hands	20
Scratching behind the ears	20
Signalling OK	10
e. Eye contact	
Looking to the right	60
Looking to the left	80
Looking up	30
Looking down	70
f. Paralinguistics	
Word fillers (*urmm/"okay"/ lah/ "so"/"that's it"*)	100
Sound of being shocked	0
Long breath of relieve	0
Pause for a moment	100
Clearing throat	10
Speaking in a fast pace	0
Speaking in a slow pace	0

3.4 Theme 2: students feelings when receiving feedback

Because students felt nervous before receiving feedback, they felt relieved after receiving feedback. They also feel very comfortable and happy with the way the lecturer gives feedback.

3.4.1 Relief

Relief can be described as peace of mind. Although students felt nervous and anxious before listening to feedback from their lecturer, they could breathe a sigh of relief when listening to the feedback from the lecturer and this has been written by several students. This is because the lecturer has shown calm facial expressions and dynamic voice intonation to create a comfortable atmosphere. Examples of their writing are as follows:

> *"That kind of eases us out of tension towards our feedback."* (K1P5).

> *"I would feel a slight relief whenever he/she puts on a smile on their face, though I must admit I would be a little nervous if they had a stern face"* (K1P8).

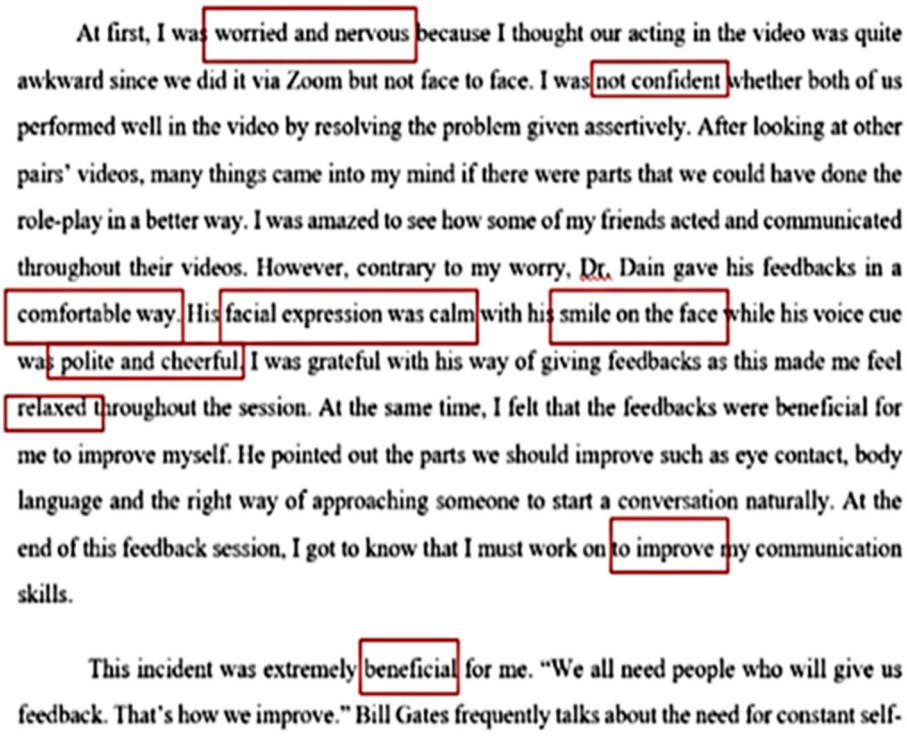
3.4.2 Comfortable

Students felt comfortable with the entire feedback session that was conducted. The feeling of comfort can be interpreted as feeling good and pleasant in a situation. This has to do with the cheerful tone and facial expression of the lecturer. This feeling can be described as below:

> *"His voice cue was not in an angry tone throughout the session. This made us feel more focused and excited throughout the session."* (K2P8).

> *"I was grateful with his way of giving feedback as this made me feel relaxed throughout the session."* (K2P3).

> *"I even felt very calm as looking Prof. smiled to us and tried to explain our mistakes."* (K1P10).



At first, I was worried and nervous because I thought our acting in the video was quite awkward since we did it via Zoom but not face to face. I was not confident whether both of us performed well in the video by resolving the problem given assertively. After looking at other pairs' videos, many things came into my mind if there were parts that we could have done the role-play in a better way. I was amazed to see how some of my friends acted and communicated throughout their videos. However, contrary to my worry, Dr. Dain gave his feedbacks in a comfortable way. His facial expression was calm with his smile on the face while his voice cue was polite and cheerful. I was grateful with his way of giving feedbacks as this made me feel relaxed throughout the session. At the same time, I felt that the feedbacks were beneficial for me to improve myself. He pointed out the parts we should improve such as eye contact, body language and the right way of approaching someone to start a conversation naturally. At the end of this feedback session, I got to know that I must work on to improve my communication skills.

This incident was extremely beneficial for me. "We all need people who will give us feedback. That's how we improve." Bill Gates frequently talks about the need for constant self-

FIGURE 5
Examples of student' reflective writing and Keyword detection for theme formation using the thematic analysis technique.

> *"This brought a great atmosphere for all of us during the session the other day."* (K1P9).

> *"I have never felt uneasy or disheartened by how my facilitators presented their feedback"* (K1P8).

> *"She definitely sets the mood right."* (K1P6).

3.4.3 Happy

Happiness is a feeling of great joy and magnanimity toward a situation that a person feels. In a comfortable atmosphere created by the lecturer during the feedback session, students stated that they felt happy with the feedback that has been given as in the statements below.

> *"I am very happy and grateful to learn the ways of communication skills with my facilitator (lecturer)"* (K2P1).

> *"This really made me relieved and happy"* (K1P4).

> *"My group members and I feel very happy because we receive a lot of positive feedback from our friends and facilitator"* (K2P2).

3.5 Theme 3: students feelings after receiving feedback

After the feedback session, students made a self-reflection on the lecturer and their performance. This included appreciation for the lecturer, understanding of the feedback that had been given, determination to improve one's performance, making improvements and further self-reflection.

3.5.1 Appreciation

The term appreciation in the context of this study can be expressed as a description or act of gratitude and respect to someone. Students appreciated the feedback given by the lecturer. This can be seen through the statements below.

> *"I felt the feedback session was very meaningful and great"* (K1P2).

> *"I believe that it has helped me a lot and I still think the same way as I am right now"* (K1P3).

> *"Prof guided me towards the right path in enhancing my communication skills."* (K1P9).

> *"I am very happy and grateful to learn the ways of communication skills with my facilitator"* (K2P1).

> *"He pointed out the parts we should improve such as eye contact, body language and the right way of approaching someone to start a conversation naturally."* (K2P2).

3.5.2 Perception

Perception is the process of creating an image in the heart or mind about something. The feedback session in the communication skill activity also improved the student's perception of the importance of communicating well. This can be seen through examples of student statements as below:

> *"Open-minded towards the acceptance of criticizing comments and viewing them from a humble angle"* (K1P7).

> *"It is very important to communicate with eye contact and the appropriate speed which can make us deliver our message more clearly and easily during the conservation"* (K2P1).

> *"We also learnt that we must adjust to different situations and audiences, especially later on when we start working as a doctor"* (K2P2).

3.5.3 Determination

Determination can be defined as a will (desire, ambition) that is very strong. In the context of this reflective writing, the students determined to improve their communication skills. After receiving feedback from the lecturer, the students felt they were determined to improve themselves, especially in communication. This is because students received good feedback from lecturers who showed different types of non-verbal communication that provided a non-threatening and comfortable space for students. Therefore, they were able to receive such feedback and improve existing deficiencies. This can be seen through examples of writing below:

> *"To know my weaknesses and strengths in communication skills to be more confident in improving my personal skills"* (K1P5).

> *"I plan to continue improving my communication skills"* (K1P8).

> *"I have learned a lot regarding communication skills and how to implement it in my daily life"* (K2P10).

3.5.4 Improvement

The definition of improvement can be said to be a process that involves the re-evaluation of something. Improvement in the context of this study refers to communication skills. It can be explained through student statements as below.

> *"I plan to continue improving my communication skills"* (K1P8).

> *"I am sure now that this is something I am working on to be better"* (K1P9).

> *"I also believe that it is very important to accept ourselves and learn from mistakes because avoid making the same mistake again in the future and continue to grow stronger as we through our life."* (K1P10).

3.5.5 Self-reflection

The nature of self-reflection after receiving feedback is important to build self-motivation in improving existing skills. Reflection is defined as the act of analyzing oneself for self-change. Students felt they were more open to receiving criticism or comments if the lecturer set a comfortable atmosphere. This could be explained through reflective writing excerpts as below:

> *"I know where I'm lacking and how I should fix it"* (K1P7).

> *"I plan to continue on improving my communication skills"* (K1P8).

> *"I am sure now that this is something I am working on to be better."* (K1P9).

> *"I also believe that it is very important to accept ourselves and learn from mistakes because avoid making the same mistake again in the future and continue to grow stronger as we through our life."* (K1P10).

> *"I am no longer to be afraid and nervous when receive feedback from someone"* (K2P1).

> *"I would not assume I have fully mastered this communication skill and I would like to talk to more people"* (K2P10).

3.6 Theme 4: observation of lecturer's types of non-verbal communication

Through students' reflective writing, four main themes could be extracted, which were the types of non-verbal communication (NVC) of lecturers observed by students. Among the most dominant NVCs told through students' reflective writing were facial expressions, voice intonation, eye contact and smile.

3.6.1 Facial expressions

A person's facial expression is the most observed during communication, especially through online applications. This is because the camera only focuses on a person's face and when speaking, facial expressions need to be refined to get a message that is parallel to the verbal message. Therefore, based on the students' reflective

writing, it was found that the lecturer's facial expressions played a very important role in making the feedback process work effectively. This is shown in the excerpts below:

> *"I felt comfortable as our facilitator did not show any expression of displeasure on her face." (K1P2).*

> *"Prof's facial expression was very calming, and I could feel the positive vibes from Prof"* (K1P1).

> *"He always puts on a smiling face and passes his comments in a very polite manner as to not hurt our feelings"* (K2P3).

However, some students stated that sometimes the lecturer gave serious facial expressions, to emphasize the message of feedback given.

> *"My facilitator uses a more neutral and serious expression when giving comments to make sure that I managed to get the main message and not repeat the same mistakes in the future"* (K1P4).

There was a student who stated that the lecturer did not show any positive facial expressions and made them wonder about the message conveyed.

> *"There are times where the facilitator would just give us a blank facial expression, and at those times I would feel rather confused or I tend to overthink and feel nervous for his/her feedback"* (K1P8).

3.6.2 Voice intonation

Voice intonation is a state of fluctuation or height of voice tone when speaking. In addition to facial expressions, voice intonation also plays an important role in providing a calm atmosphere for a feedback session to take place. This is because, based on the students' reflective writing, they felt very anxious and nervous before receiving any feedback.

> *"…tone from the facilitator were really positive and full of motivation that makes me feel comfortable and able to receive the advice effectively."* (K1P1).

> *"She delivers her comments in a calm facial expression and a gentle tone."* (K1P5).

> *"Soft spoken and encouraging towards our efforts and capabilities"* (K1P8).

There were also comments stating that a firm and serious voice tone helps ensure that the conveyed message is accurate and tells students to take it seriously when it comes to improving their performance in communication.

> *"My facilitators use a serious tone when giving feedback to make sure that I got the take-home message."* (K2P8).

3.6.3 Eye contact

Eye contact is the movement of the eyes to the right or to the left without moving the head. Since the entire feedback session was face-to-face and the lecturer looked toward the camera, eye contact could also influence the message conveyed. It can be seen through student writing as below:

> *"One thing would be that making eye contact when appropriate is important when talking to someone to ensure that the conversation is bidirectional and for both to receive inputs from it."* (K1P7).

3.6.4 Smile

A smile can be described as the movement of the lips which is charming and can soften the heart. A smile can affect the students' feelings when receiving feedback from the lecturer. This is shown in the excerpt below:

> *"Prof put on a pleasant smile, and I did not feel any sense of discomfort from her."* (K1P5).

The findings of this study have been organized according to the themes that have been processed through deductive analysis for the types of non-verbal communication and also inductive analysis for students' reflective writing. Through the findings of this study, it can be concluded that several types of non-verbal communication can be observed online. Students' acceptance when receiving feedback is good if the lecturer's non-verbal communication supports the information conveyed by providing a cheerful and comfortable atmosphere.

4 Discussion

4.1 Observation of types of non-verbal communication online

Non-verbal communication (NVC) is the transfer of information using body language including eye contact, facial expressions, gestures, and voice (9). NVC is a habit and often reinforces the message to be conveyed through oral communication. Therefore, it is important to study non-verbal means of communication-based on observation and analysis of physical movements, using language to transfer information through written texts, spoken or sign language. Recent studies show that communication skills among medical students are lacking, especially in the context of NVC and empathy toward patients (2–4). Feedback can improve medical students' NVC during communication, especially through facial expressions, movements, body posture, silent intervals, and laughter (8). Therefore, this study must be conducted by observing how a feedback process is delivered especially through a synchronous online platform.

4.1.1 Body position

Body position is important to complement the way feedback is given. This is easily captured by the camera as it can detect the body's position toward the camera. In the observation made online synchronously, the position of the body can be seen mainly from the chest level to the head. The overall position of the body can be seen

well, whether it appears to be sitting upright or leaning to the left or right. A good position for video recording is sitting upright and facing the camera. This shows that lecturers are always alert and ready to give feedback (18). Under this theme, most lecturers were seen sitting straight and upright (90%) and leaning toward the camera (100%). However, one lecturer was seen to always lean more to the left, which indicates a comfortable position when giving feedback (19).

4.1.2 Facial expressions

Facial expressions play an important role in understanding a person's feelings as an explanation of what the words are trying to convey. Various atmospheres, emotions, and attitudes can affect the learning environment positively or negatively. Therefore, these factors can be presented through various expressions (20). The human face can be so expressive that it conveys countless emotions without having to say a word. Facial expressions of happiness, sadness, anger, surprise, fear, and ugliness are similar across all cultures and societies around the world (21). Observations through this study show that all lecturers (100%) were seen smiling when giving feedback which gives a sense of safety and comfort to the students. Smiles are necessary to increase the sense of satisfaction with the activities that have been done by students (22, 23). Smiles provide positive feedback and involve the affective domain by conveying comfort, trust, friendliness, interest, joy, or surprise (24). A frown conveys displeasure, disapproval, and anger, a deadpan expression conveys disbelief, low energy, and disinterest (25). However, none of the lecturers frowned during the feedback session. Conversely, a lack of facial expression can be boring and should also be avoided (26). Therefore, facial expressions should always give a positive message to make students feel comfortable in receiving feedback.

4.1.3 Voice intonation

A cheerful voice intonation can attract the attention of students to focus fully on feedback (27, 28). However, a cheerful and dynamic voice will complement the movement of the body, through appropriate tone and volume, to ensure the correct message is delivered (24). It can be seen from this study that all the lecturers delivered their feedback with a dynamic tone of voice to create a comfortable and safe zone for students to receive feedback. It can be measured through online platforms (5) and via student reception to voice intonation. Intonation can be associated with feelings of joy, anger, and sadness (29). A study on feedback from lecturers through audio recordings showed students can well receive the feedback given if the intonation of the lecturer's voice is cheerful and not frightening (30). Therefore, a cheerful and calm voice intonation is essential in delivering the message to the student that the feedback session should not be avoided and should take place in a comfortable environment. The emphasis on the message delivered can also be reinforced with appropriate vocal intonation.

4.1.4 Body movement

Body movement is the essence of a thousand and one messages that can be conveyed through NVC. For example, you may be able to gesture or use your hands when debating or speaking passionately as an example of NVC to show that you are a very focused and serious person when speaking. It also gives an impression to someone that your words or messages can be trusted. However, some body language can have very different meanings between cultures around the world. From 10 observations of body gestures observed through a synchronous online platform, large hand movements were seen to be the most dominant of all body gestures (100%). The most obvious indicator used to emphasize the information conveyed was hand movement within the camera frame. Observations in this study were in line with previous studies that showed lecturers extending their hands, with the palms facing slightly toward the camera (27). This shows a willingness to communicate and share ideas. It turns out that this gesture needs to be made to repeat the information given. However, if this gesture is done excessively, it may distract people to focus more on the hand than the idea or information conveyed. Movement of one's hands and arms can also emphasize one thing; and continue to attract attention to determine whether something is important (31). This can be seen among lecturers who show good signs of asking for confirmation from students. Hand movements also show how enthusiastic a person is in conveying information (26). Small movements such as scratching the face and body and touching the glasses are normal, if not done regularly and deliberately.

4.1.5 Eye contact

Since visual perception is dominant among most people, eye contact is a very important type of NVC. Information can be conveyed by just looking at someone, such as interest, affection, hostility, or attraction. Looking into someone's eyes when talking is also important in ensuring that the conversation remains interesting and it can also tell whether a person is interested and reacts to the message conveyed (21). Therefore, if feedback is given through an online platform, the individual must look toward the camera as if looking into someone's eyes. If feedback is given in a small group, looking at the participant's screen will give the effect of looking without staring. Looking left and right when giving feedback is common as a process of remembering information (32). However, it should be avoided from being done excessively to prevent a reduction in student's focus levels (21).

4.1.6 Paralinguistics

Emphasizing conveyed messages through sound is a habit done by individuals. It is a habitual process in non-verbal communication techniques starting from children (33) up to adults (34). Paralinguistics is a sound that occurs with or replaces words, including tone of voice; and sounds of sighing, crying, and other non-verbal sounds (21). This can be reflected by the words "errrm," "okay," "aaaah" which are common in everyday conversation but should be reduced to avoid unnecessary disruption of the feedback process (35, 36). However, for every process of giving information in a conversation or speech, pausing for a moment is important to ensure that every message conveyed is easily understood (37). Therefore, an individual should balance the frequency of pausing for a moment, so that the information conveyed is not interrupted. Every activity that uses language or tests affective skills will involve paralinguistics. For example, through communication activities using a foreign language, paralinguistics is widely used especially in terms of voice quality and voice emphasis to explain the message conveyed (38). It turns out that the use of paralinguistics is important to help the delivery of information and it can influence how individuals receive it.

4.2 Reflective writing

Reflective writing is an effective way for students to integrate professional experience and academic learning (39). When used

effectively, reflective writing can improve students' understanding of the knowledge concept being studied. This approach can help students to critically evaluate the nature of their professionalism for lifelong learning (40). In this study, students made self-reflection on their performance in communication skills and how non-verbal communication by their lecturers conveys messages during feedback sessions.

4.2.1 Student's feelings before receiving feedback

Students' acceptance of the feedback session from their lecturer increased the feeling of nervousness and anxiety among them. This is because students felt that their performance was not satisfactory when performing communication skill activities. The observations that have been carried out in this study were consistent with various other studies, especially through learning a new language course, where students feel that before feedback is given, they express feelings of nervousness and anxiety (41, 42). This is because feedback is meant to show their weaknesses for improvement (43). They were also worried that their performance did not meet the expectations set by the lecturer (44). This feeling was normal, especially among medical students who have high expectations of their performance (45). However, this feeling can be reduced if feedback is given via video recording, rather than synchronously online (7, 46–48) and then students would be able to make better self-reflection and improvement (8, 38). Students who have high feelings of nervousness, anxiety, fear and apprehension before receiving feedback can be associated with having a good learning curve and a high self-reflection process (49). Although this kind of feeling is unavoidable, it may be reduced by providing a comfortable learning environment especially when an activity takes place and when receiving feedback from the lecturer.

4.2.2 Student's feelings when receiving feedback

The findings of this study show that students felt very relieved, comfortable, and happy to receive feedback given by the lecturer. The same observation was also recorded in other studies that show that the role of lecturers is to convince students of their performance and strive to improve without feeling sad and afraid (50, 51). Students also need to be often reminded that the feedback process is important as an intermediary medium in delivering accurate information for improvement along with self-reflection (38, 52). This is also related to the negative feelings and expectations of students toward lecturers before receiving feedback (43). Happy feelings among students can lead to good self-reflection techniques and subsequently be able to improve communication skills (40, 47, 53, 54). Therefore, the type of non-verbal communication a lecturer uses can help students receive feedback on their performance in a calm and comfortable situation.

4.2.3 Student's feelings after receiving feedback

Students' reflective writing also described how they felt after receiving feedback. After their lecturers provide feedback on their performance in communication skills, they continue to self-reflect on how to improve their skills (53). They appreciate feedback that has been delivered with a good and positive type of non-verbal communication. This is in line with previous studies that share similar findings on the appreciation shown by students to their teachers/lecturers/mentors, it turns out that they have received feedback well (41, 55–57).

Medical students in this study are also seen to have their perception of the importance of communication skills in the field of medicine. This may be due to the student's experience in communicating with various parties, especially in preparing for an activity (23, 58, 59). Students who write about the importance of communication have high reflection skills and can be used as intrinsic motivation that allows the improvement process to be more successful (8, 51, 60). Therefore, if a student has a perception of the importance of something, it will facilitate a lifelong learning process and they will become medical students who constantly improve themselves.

Students also wrote about their determination to improve their weaknesses in communication skills. Students' determination to improve their weaknesses is also associated with statements to improve their performance (9, 46). This is related to receiving good feedback from lecturers and the perception of the importance of communicating (61). Students also associate receiving good feedback from their lecturer through good non-verbal communication also increases their determination (36, 56). This is also in line with previous studies that show the good effects of NVC, which include creating a student who is aware of his own weaknesses and can work on being better (1, 50, 62–64). Therefore, NVC is very important to set a conducive learning environment for students' self-development.

Improvements that have been written by students are based on self-reflection. The process of self-reflection usually fulfils three main conditions namely the nature of openness in seeing things from various angles, observing the performance of oneself and others and making good comparisons, and taking an objective approach in answering any questions or problems (40). It also needs to be accompanied by an organized plan to ensure the improvement process runs smoothly. This includes providing learning plans, implementation of strategies, plans, conducive learning spaces, repeated reflection processes, and continuous evaluation (65). Observations from this study are in line with previous studies that show that students are determined to improve their weaknesses and it is driven by a high level of reflection (66). Therefore, with detailed planning and support from lecturers, the improvement process planned by students will successfully improve their communication skills.

4.2.4 Observation of types of non-verbal communication among lecturers

Students' reflective writing was also found to have observed some types of non-verbal communication (NVC) of lecturers. This includes facial expressions, voice intonation, eye contact and smiles. This is in line with previous studies that show the types of NVC that are often observed by students (67). If compared with data from observations through a synchronous online platform, lecturers mostly exhibit facing the camera, moving hands while giving feedback and episodes pausing and looking left and right when remembering information. However, students only look toward cheerful facial expressions, which are accompanied by soft and calm voice intonation, eye gaze and a smile which provides a calm and appropriate atmosphere for feedback giving. This is in line with the findings of previous studies that show students only see facial expressions including the way of speaking,

intonation and smile (5, 8, 62). Therefore, it is important for lecturers to always maintain a cheerful facial expression accompanied by a positive aura when giving feedback to students, whether through synchronous online platforms, asynchronous, video recordings or face-to-face methods.

A recent investigation conducted in Malaysia revealed a notable prevalence of non-verbal communication (NVC) within the context of Arabic language instruction as perceived by students. This observation underscores the significance of visual cues alongside auditory comprehension in face-to-face communication settings, wherein students not only rely on listening skills to grasp verbal information but also on the observation of NVC cues employed by their instructors (68). Similarly, a separate study focusing on the communication skills of medical students found that a considerable portion, ranging from 2 to 13%, required active support and encouragement from faculty members (69). This underscores the notion that effective communication skills are not inherently acquired, warranting medical schools to prioritize the cultivation of comprehensive communication abilities among future physicians. The various forms of non-verbal communication demonstrated by educators hold significance as they can influence students' inherent tendencies to address deficiencies in communication. Reflecting on a cohort of medical students from the Faculty of Medicine at the National University of Malaysia who participated in a virtual patient software program, DxR Clinician, during their psychiatry rotation, the significance of interactions with instructors during debriefing sessions became apparent (70). While the group-based learning facilitated by the virtual patient software offered prompt feedback through assessment outcomes, students expressed a desire for additional opportunities for direct inquiry and personalized feedback from their instructors. Consequently, in online feedback sessions, student receptivity assumes significance, as it enables them to discern the congruence between verbal feedback and the instructor's non-verbal communication cues.

4.2.5 Application of non-verbal communication in the advancement of technology

In the near future, chatbots and other digital aid tools like artificial intelligence (AI) in medicine will be used extensively for doctor-patient communication. Majority of studies on the application of extended reality technology concentrate on its value in medical education; nevertheless, there is still much to learn about the genuine consequences of this technology's use in face-to-face physician-patient interactions (71). A recent German study investigated on the attitudes of medical students toward AI and chatbots in medicine. The students thought that using chatbots as interactive diaries or therapy tools would be a useful way to lessen patients' feelings of guilt, shyness, and anonymity while sharing sensitive and painful information. However, it was believed that interpersonal information would be lost and nonverbal contact with a chatbot could worsen doctor-patient relationships (72). Therefore, it was thought that the initial face-to-face interaction between the physician and patient was essential. It is also shown that artificial empathy can identify emotions in profile and 3/4 view photos, making it a potentially useful assessment tool for examining patient-doctor interactions in real-world clinical situations (73).

5 Limitations and recommendations

5.1 Findings of observation

All the lecturers involved in this study have known that they will be recorded while carrying out communication skills activities with students. Therefore, the type of NVC observed through online video recordings may seem contrived. However, there are two suggestions to overcome this problem. Observations that have been made by researchers only record the type of NVC that is made repeatedly over a long period. This is called repetitive behavior or habitual movement that is done unconsciously. For example, if a person touches the frame of the glasses 10 times in 5 min, that shows repetitive behavior and should be considered as a genuine finding.

The next suggestion that can be put into practice in future studies is to look at the types of NVC retrospectively. Virtual teaching and learning involved a lot of video recording for review purposes. Therefore, to obtain a holistic, unbiased and multi-angle observation, retrospective observation without the lecturer being aware that he is being recorded will add impact value to this study. This is because these studies generally show good types of NVC.

5.2 Increasing the number of samples

Since the observations in this study involved only 10 lecturers, if improvement can be made to the study sample, it can show a comparison of the types of NVC exhibited by younger lecturers and more senior lecturers. Increasing the number of samples can also diversify types of NVC between the sexes. This study also only looks at preclinical lecturers in communication skills activities. This can be expanded to observe the types of NVC among clinical lecturers and the acceptance of students who have more experience receiving good or bad feedback can also be discussed.

5.3 Focused discussion groups

The findings of this study were able to open the paradigm of future studies by forming focused discussion groups among medical students to see which types of NVC are more dominant and preferred, and how students receive feedback through various NVC shown by lecturers. The discussion group can also be focused on the lecturers to observe and find out why certain NVC is performed. This is to better understand whether the NVC exhibited can improve on how a message is interpreted to influence the intrinsic nature of students. This suggestion is expected to train lecturers to provide feedback well to students as a continuous assessment effort.

6 Conclusion

The study of observing the types of NVC online is indeed very important to explore the dominant types of NVC that can be identified by students to receive good feedback. Lecturers need to provide a calm and cheerful atmosphere to encourage students' openness in receiving feedback and to make them feel comfortable. Positive feedback will

give students a happy feeling. Facial expressions, voice intonation, frequent hand movements, eye contact and smiles are findings that are often observed among lecturers during feedback sessions. Students' acceptance of these types of NVC were extracted from their reflective writing.

Reflective writing shows that students feel very anxious and nervous before receiving feedback because they think about their poor performance. This may be due to high expectations of oneself and fear of receiving negative evaluations. However, this increases their determination to improve their weaknesses. Since students can observe positive NVC from their lecturer (smile, soft voice intonation) which provides a calm atmosphere, they feel relieved and can accept the feedback that has been given. The importance of providing a calm and comfortable atmosphere will affect how students receive feedback. Therefore, this reflective writing complements the observation through a synchronous online platform that shows positive NVC observation from the lecturer. All the findings of this study are important to guide lecturers to convey information accompanied by good NVC.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statement

The studies involving humans were approved by Research Ethics Committee Universiti Kebangsaan Malaysia. JEP-2020-718. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

NI: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. NM: Writing – original draft, Writing – review & editing, Data curation, Visualization. SB: Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. MB: Conceptualization, Formal analysis, Funding acquisition, Investigation, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. The Faculty of Medicine UKM is supporting the publication of this study FF-2020-718. This research was conducted without any external funding or financial support.

Acknowledgments

We would like to thank all the participants involved in this project. We also extend our acknowledgement to the Faculty of Medicine, National University of Malaysia (UKM) for their continuous support toward this study.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2024.1375982/full#supplementary-material

References

1. Aziz A, Farhan F, Hassan F, Qaiser A. Words are just noise, let your actions speak: impact of nonverbal communication on undergraduate medical education. *Pakistan J Medical Sci*. (2021) 37:1849–53. doi: 10.12669/pjms.37.7.4180

2. Baugh AD, Vanderbilt AA, Baugh RF. Communication training is inadequate: the role of deception, non-verbal communication, and cultural proficiency. *Med Educ Online*. (2020) 25:1820228. doi: 10.1080/10872981.2020.1820228

3. Graf J, Loda T, Zipfel S, Wosnik A, Mohr D, Herrmann-Werner A. Communication skills of medical students: survey of self- and external perception in a longitudinally based trend study. *BMC Med Educ*. (2020) 20:1–10. doi: 10.1186/s12909-020-02049-w

4. Vogel D, Meyer M, Harendza S. Verbal and non-verbal communication skills including empathy during history taking of undergraduate medical students. *BMC Med Educ*. (2018) 18:1–7. doi: 10.1186/s12909-018-1260-9

5. Aziz A, Khan AM, Niazi Z, Mirza TI, Fazal S. Actions speak louder than words: impact of kinesics on undergraduate medical education. *J Ayub Medical College, Abbottabad: JAMC*. (2021) 33:628–33.

6. Bailenson JN. Nonverbal overload: A theoretical argument for the causes of zoom fatigue. *Technol, Mind Behav*. (2021) 2. doi: 10.1037/tmb0000030

7. Dohms MC, Collares CF, Tibério IC. Video-based feedback using real consultations for a formative assessment in communication skills. *BMC Med Educ*. (2020) 20:57–9. doi: 10.1186/s12909-020-1955-6

8. Liu C, Lim RL, McCabe KL, Taylor S, Calvo RA. A web-based telehealth training platform incorporating automated nonverbal behavior feedback for teaching communication skills to medical students: A randomized crossover study. *J Med Internet Res*. (2016) 18:e246. doi: 10.2196/jmir.6299

9. Liu C, Lim R, Taylor S, Calvo RA. Students' behavioural engagement in reviewing their tele-consultation feedback within an online clinical communication skills platform. *Comput Hum Behav*. (2019) 94:35–44. doi: 10.1016/j.chb.2019.01.002

10. Braun V, Clarke V. Thematic analysis In: H Cooper, PM Camic, DL Long, AT Panter, D Rindskopf and KJ Sher, editors. *APA handbook of research methods in psychology, Research designs: Quantitative, qualitative, neuropsychological, and biological*, vol. *2*. US: American Psychological Association (2012). 57–71.

11. Uygur J, Stuart E, Paor MD, Wallace E, Duffy S, O'Shea M, et al. A Best Evidence in Medical Education systematic review to determine the most effective teaching methods that develop reflection in medical students: BEME Guide No. 51. *Medical Teacher*. (2019) 41:3–16. doi: 10.1080/0142159X.2018.1505037

12. Wald HS, White J, Reis SP, Esquibel AY, Anthony D. Grappling with complexity: Medical students' reflective writings about challenging patient encounters as a window into professional identity formation. *Medical Teacher*. (2019) 41:152–60. doi: 10.1080/0142159X.2018.1475727

13. Carlson MD, Morrison RS. Study design, precision, and validity in observational studies. *J Palliat Med*. (2009) 12:77–82. doi: 10.1089/jpm.2008.9690

14. Pinquart M. Experimental studies and observational studies In: D Gu and ME Dupre, editors. *Encyclopedia of gerontology and population aging*. Cham: Springer (2021)

15. Microsoft Teams. Available at: https://www.microsoft.com/en-my/microsoft-teams/log-in. Accessed 1st January 2021.

16. Vasileiou K, Barnett J, Thorpe S, Young T. Characterising and justifying sample size sufficiency in interview-based studies: systematic analysis of qualitative health research over a 15-year period. *BMC Med Res Methodol*. (2018) 18:148. doi: 10.1186/s12874-018-0594-7

17. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol*. (2006) 3:77–101. doi: 10.1191/1478088706qp063oa

18. Cherry K. *Understanding body language and facial expressions* (2023).

19. Pease B, Pease A. *The definitive book of body language: The Hidden Meaning Behind People's Gestures and Expressions* (2006) USA: Bantam.

20. Elfenbein H. No learning in emotion judgements: training and the cross-cultural understanding of facial expressions. *J Nonverbal Behav*. (2006) 30:21–36. doi: 10.1007/s10919-005-0002-y

21. Brookhart S. *How to give effective feedback to your students* (2008). 56 p.

22. Beamish AJ, Foster JJ, Edwards H, Olbers T. What's in a smile? A review of the benefits of the clinician's smile. *Postgrad Med J*. (2019) 95:91–5. doi: 10.1136/postgradmedj-2018-136286

23. Moral RR, Andrade-Rosa C, Martín JDM, Barba EC, de Torres LP, Martín DM. Effectiveness of a communication skills training program for medical students to identify patients communicative clues. *Patient Educ Couns*. (2020) 103:2384–7. doi: 10.1016/j.pec.2020.05.018

24. Nikitin J, Freund AM. The motivational power of the happy face. *Brain Sci*. (2019) 9:6. doi: 10.3390/brainsci9010006

25. Jaques N, McDuff D, Kim YL, Picard R. Understanding and predicting bonding in conversations using thin slices of facial expressions and body language. *Intelligent Virtual Agents*. (2016) 10011 LNAI:64–74. doi: 10.1007/978-3-319-47665-0_6

26. Hale AJ, Freed J, Ricotta D, Farris G, Smith CC. Twelve tips for effective body language for medical educators. *Med Teach*. (2017) 39:1–6. doi: 10.1080/0142159X.2017.1324140

27. Gorton K, Allday RA, Lane JD, Ault MJ. Effects of brief training plus electronic feedback on increasing quantity and intonation of behavior specific praise among preschool teachers. *J Behav Educ*. (2021) 11:1–20. doi: 10.1007/s10864-020-09427-w

28. Guyer JJ, Fabrigar LR, Vaughan-Johnston TI. Speech rate, intonation, and pitch: investigating the Bias and Cue effects of vocal confidence on persuasion. *Personal Soc Psychol Bull*. (2019) 45:389–405. doi: 10.1177/0146167218787805

29. Moridis CN, Economides AA. Affective learning: empathetic agents with emotional facial and tone of voice expressions. *IEEE Trans Affect Comput*. (2012) 3:260–72. doi: 10.1109/T-AFFC.2012.6

30. Heimbürger A, Isomöttönen V. Moderating cultural effects in a higher e-education context? Supervisor's tone of voice in recorded audio feedback. *Proceedings - Front Educ Conference*. (2017) 2017:1–5. doi: 10.1109/FIE.2017.8190646

31. Jafine H. Dramatic health: an exploration of empathy and communication through applied drama. *Med Educ*. (2011) 45:10.

32. Patterson ML. Nonverbal communication. *The Curated Reference Collection in Neurosci Biobehav Psychol*. (2016):731–8. doi: 10.1016/B978-0-12-809324-5.06502-0

33. Zukeflli NN, Subramaniam V. Paralinguistik dalam Pemerolehan Bahasa Kanak-Kanak. *Int J Lang Educ Applied Linguistics*. (2018) 8:1–13. doi: 10.15282/ijleal.v8.526

34. Schuller B, Steidl S, Batliner A, Burkhardt F, Devillers L, Müller C, et al. Paralinguistics in speech and language - state-of-the-art and the challenge. *Comput Speech Lang*. (2013) 27:4–39. doi: 10.1016/j.csl.2012.02.005

35. Mariam S. The Use of Fillers and Hesitation Devices as Communication Strategies Among Malaysian Language Learners. *Infrastructure University Kuala Lumpur Res J*. (2014) 2:162–75.

36. Vinciarelli A, Chatziioannou P, Esposito A. When the words are not everything: the use of laughter, fillers, back-channel, silence, and overlapping speech in phone calls. *Frontiers in ICT*. (2015) 2:1–11. doi: 10.3389/fict.2015.00004

37. Johar S. *Emotion, Affect and Personality in Speech: The Bias of Language and Paralanguage*. Cham: Springer International Publishing (2016).

38. Zick A, Granieri M, Makoul G. First-year medical students' assessment of their own communication skills: A video-based, open-ended approach. *Patient Educ Couns*. (2007) 68:161–6. doi: 10.1016/j.pec.2007.05.018

39. Song P, Stewart R. Reflective writing in medical education. *Med Teach*. (2012) 34:955–6. doi: 10.3109/0142159X.2012.716552

40. Sandars J. The use of reflection in medical education: AMEE guide no. 44. *Med Teach*. (2009) 31:685–95. doi: 10.1080/01421590903050374

41. Di Loreto S, McDonough K. The relationship between instructor feedback and ESL student anxiety. *TESL Canada J*. (2014) 31:20. doi: 10.18806/tesl.v31i1.1165

42. Henderson M, Phillips M. Video-based feedback on student assessment: scarily personal. *Australas J Educ Technol*. (2015) 31:51–66. doi: 10.14742/ajet.1878

43. Zhang LJ, Rahimi M. EFL learners' anxiety level and their beliefs about corrective feedback in oral communication classes. *System*. (2014) 42:429–39. doi: 10.1016/j.system.2014.01.012

44. Shafique N, Gul S, Raseed S. Perfectionism and perceived stress: the role of fear of negative evaluation. *Int J Ment Health*. (2017) 46:312–26. doi: 10.1080/00207411.2017.1345046

45. Cipra C, Müller-Hilke B. Testing anxiety in undergraduate medical students and its correlation with different learning approaches. *PLoS One*. (2019) 14:e0210130–11. doi: 10.1371/journal.pone.0210130

46. Kam BS, Yune SJ, Lee SY, Im SJ, Baek SY. Impact of video feedback system on medical students' perception of their clinical performance assessment. *BMC Med Educ*. (2019) 19:252–7. doi: 10.1186/s12909-019-1688-6

47. Killingback C, Drury D, Mahato P, Williams J. Student feedback delivery modes: A qualitative study of student and lecturer views. *Nurse Educ Today*. (2020) 84:104237. doi: 10.1016/j.nedt.2019.104237

48. Schmidt M, Freund Y, Alves M, Monsel A, Labbe V, Darnal E, et al. Video-based feedback of oral clinical presentations reduces the anxiety of ICU medical students: A multicentre, prospective, randomized study. *BMC Med Educ*. (2014) 14:103. doi: 10.1186/1472-6920-14-103

49. Jones DL, Nelson JD, Opitz B. Increased anxiety is associated with better learning from negative feedback. *Psychol Learn Teach*. (2021) 20:76–90. doi: 10.1177/1475725720965761

50. Bambaeeroo F, Shokrpour N. The impact of the teachers' non-verbal communication on success in teaching. *J Adv Med Educ Prof*. (2017) 5:51–9.

51. White CB. Smoothing out transitions: how pedagogy influences medical students' achievement of self-regulated learning goals. *Adv Health Sci Educ*. (2007) 12:279–97. doi: 10.1007/s10459-006-9000-z

52. Karnieli-Miller O, Michael K, Gothelf AB, Palombo M, Meitar D. The associations between reflective ability and communication skills among medical students. *Patient Educ Couns*. (2021) 104:92–8. doi: 10.1016/j.pec.2020.06.028

53. Qureshi NS. Giving effective feedback in medical education. *The Obstetrician & Gynaecologist*. (2017) 19:243–8. doi: 10.1111/tog.12391

54. Ruiz-Moral R, Pérula de Torres L, Monge D, García Leonardo C, Caballero F. Teaching medical students to express empathy by exploring patient emotions and experiences in standardized medical encounters. *Patient Educ Couns*. (2017) 100:1694–700. doi: 10.1016/j.pec.2017.04.018

55. Dixson MD, Greenwell MR, Rogers-Stacy C, Weister T, Lauer S. Nonverbal immediacy behaviors and online student engagement: bringing past instructional research into the present virtual classroom. *Commun Educ*. (2017) 66:37–53. doi: 10.1080/03634523.2016.1209222

56. Kim EJ, Lee KR. Effects of an examiner's positive and negative feedback on self-assessment of skill performance, emotional response, and self-efficacy in Korea: A quasi-experimental study. *BMC Med Educ*. (2019) 19:1–7. doi: 10.1186/s12909-019-1595-x

57. Kandevani NY, Labaf A, Mirzazadeh A, Pormehr PS. Attitudes toward learning communication skills among Iranian medical students. *BMC Med Educ*. (2024) 24:193. doi: 10.1186/s12909-024-05140-8

58. Engerer C, Berberat PO, Dinkel A, Rudolph B, Sattel H, Wuensch A. Specific feedback makes medical students better communicators. *BMC Med Educ*. (2019) 19:51–8. doi: 10.1186/s12909-019-1470-9

59. Salam A, Song CO, Mazlan NF, Hassin H, Lee LS, Abdullah MH. Professionalism of future medical professionals in Universiti Kebangsaan Malaysia (UKM) medical Centre. *Intern Med J*. (2012) 60:534–40. doi: 10.1016/j.sbspro.2012.09.419

60. Williams K, Williams C. Five key ingredients for improving student motivation. *Res High Educ J*. (2011) 197:1215–22. doi: 10.1016/j.sbspro.2015.07.382

61. Sheerman-chase T. On the automatic recognition of facial non-verbal communication meaning in informal, spontaneous conversation. *Computer Science, Linguistics, Psychology in proceeding*. (2012). doi: 10.13140/2.1.3908.9288

62. Ibrahim NA, Abdul Rani NS, Jamri MH, Bakar MH, Abdul Wahab S, Mahbob MH, et al. The importance of non-verbal communication in organizations. *Int J Acad Res Business Soc Sci*. (2022) 12:1841–51. doi: 10.6007/IJARBSS/v12-i6/13901

63. Haneef M, Faisal MA, Alvi AK, Zulfiqar M. The Role of Non-Verbal Communication in Teaching Practice. *Sci Int(Lahore)*. (2014) 4:513–7.

64. Venter E. Challenges for meaningful interpersonal communication in a digital era. *HTS Teologiese Stud / Theological Stud*. (2019) 75:1–6. doi: 10.4102/hts.v75i1.5339

65. Aronson L. Twelve tips for teaching reflection at all levels of medical education. *Med Teach*. (2011) 33:200–5. doi: 10.3109/0142159X.2010.507714

66. Chan KD, Humphreys L, Mey A, Holland C, Wu C, Rogers GD. Beyond communication training: the MaRIS model for developing medical students' human capabilities and personal resilience. *Med Teach*. (2020) 42:187–95. doi: 10.1080/0142159X.2019.1670340

67. Park KH, Park SG. The effect of communication training using standardized patients on nonverbal behaviors in medical students. *Korean J Med Educ*. (2018) 30:153–9. doi: 10.3946/kjme.2018.90

68. Baharudin H, Abdullah NH. The Arabic Teachers' level of nonverbal communication Practise in Lughatul Fasli. *Sociol Sci*. (2023) 13:333–44. doi: 10.6007/IJARBSS/v13-i7/17690

69. Salam A, Zakaria H, Abdelhalim AT, Lim CC, Alsharkawy A, Taibi MK, et al. Communication skills of fresh medical graduates in a Malaysian private university. *Bangladesh J Medical Sci*. (2022) 21:404–12. doi: 10.3329/bjms.v21i2.58074

70. Woon LS, Mohd Daud TI, Tong SF. "It kinda helped us to be there": students' perspectives on the use of virtual patient software in psychiatry posting. *BMC Med Educ*. (2023) 23:851. doi: 10.1186/s12909-023-04834-9

71. Ahuja AS, Polascik BW, Doddapaneni D, Byrnes ES, Sridhar J. The digital metaverse: applications in artificial intelligence, medical education, and integrative health. *Integrative Med Res*. (2023) 12:100917. doi: 10.1016/j.imr.2022.100917

72. Moldt JA, Festl-Wietek T, Madany Mamlouk A, Nieselt K, Fuhl W, Herrmann-Werner A. Chatbots for future docs: exploring medical students' attitudes and knowledge towards artificial intelligence and medical chatbots. *Med Educ Online*. (2023) 28:2182659. doi: 10.1080/10872981.2023.2182659

73. Huang CW, Wu BC, Nguyen PA, Wang HH, Kao CC, Lee PC, et al. Emotion recognition in doctor-patient interactions from real-world clinical video database: initial development of artificial empathy. *Comput Methods Prog Biomed*. (2023) 233:107480. doi: 10.1016/j.cmpb.2023.107480

frontiers | Frontiers in Medicine

TYPE Original Research
PUBLISHED 28 May 2024
DOI 10.3389/fmed.2024.1342654

OPEN ACCESS

EDITED BY
Muhammad Azeem Ashraf,
Hunan University, China

REVIEWED BY
Michael J. Wolyniak,
Hampden–Sydney College, United States
Shazia Irum,
Shifa College of Medicine, Pakistan

*CORRESPONDENCE
Nadia Shabnam
✉ nadia.shabnam@numspak.edu.pk;
✉ nadiakhan.qau@gmail.com

RECEIVED 22 November 2023
ACCEPTED 18 April 2024
PUBLISHED 28 May 2024

CITATION
Sadiq N, Fatima SH, Shabnam N and Rauf A (2024) Empowering health professions educators: enhancing curriculum delivery through customized e-tutorial training on fundamental digital tools.
Front. Med. 11:1342654.
doi: 10.3389/fmed.2024.1342654

Empowering health professions educators: enhancing curriculum delivery through customized e-tutorial training on fundamental digital tools

Naushaba Sadiq, Syeda Hanaa Fatima, Nadia Shabnam* and Ayesha Rauf

National University of Medical Sciences (NUMS), Rawalpindi, Pakistan

Introduction: In the dynamic landscape of education, the fusion of technology and learning, commonly termed "technology-enhanced learning" (TEL), has emerged as a transformative phenomenon. This study focuses on the imperative integration of TEL in medical education, recognizing the diverse digital literacy levels of adult learners. The exploration introduces the innovative E-Portal training program, designed to empower health professions educators with essential skills for proficiently employing digital tools in instruction.

Methodology: A dedicated team of medical educationists conducted a thorough investigation into E-curriculum design and delivery, employing the Moodle Learning Management System as the foundation for the E-Portal training program. The training, spanning crucial stages such as course design, content delivery, self-paced teaching, and quality assessment, facilitated participant progression at individual paces, unlocking subsequent steps upon meeting stipulated prerequisites. A pre-training questionnaire gauged participants' comprehension of distance learning, e-learning, synchronous and asynchronous teaching, and self-directed study. Subsequent focus group discussion post-training generated rich insights into participants' experiences, reflections, and identified challenges.

Results: The results illuminate participants' limited adeptness with e-learning terminology, successful assimilation of components and functionalities, and heightened confidence in online teaching practices. However, discerned challenges during implementation, such as technical hurdles and engagement issues, highlight the multifaceted nature of TEL integration. While the E-Portal training positively impacted preparedness, participant feedback advocates for improvements in assessment tools, technical training provisions, and exploration of alternative Learning Management Systems.

Discussion and conclusion: Study emphasizes the ongoing need for diverse training methodologies across Learning Management Systems, acknowledging the evolving nature of education and technology. This study underscores the transformative role of a tailored E-Portal training program in seamlessly integrating digital tools into medical education. The comprehensive insights provided contribute to a nuanced understanding of the advantages, obstacles, and potential avenues for enhancement in curriculum delivery through technology-enhanced learning, thereby propelling the field forward.

KEYWORDS

curriculum, teaching, assessment process, health professions, Pakistan, e-tutorial training

Introduction

The use of information and communication technologies in teaching and learning is referred to as "technology-enhanced learning" (TEL) (1); a potent phenomenon that has emerged from the convergence of technology and education in today's fast-paced world (2). This ground-breaking approach to education is transforming conventional teaching strategies, and giving students never-before-seen chances to gain knowledge, skills, and competences in creative ways.

The demand for digital competency among educators has become increasingly imperative in response to evolving educational paradigms (3).

The imperative to embrace TEL in medical education remains strong, driven by the growing demand for innovative learning approaches, the increasing prevalence of digital natives among student populations, and the expanding scope of virtual healthcare delivery (4). By understanding and addressing the barriers to TEL integration, educators and institutions can unlock the full potential of technology to enhance teaching and learning experiences, empower learners, and shape the future of medical education (4).

As educators strive to harness the power of technology to meet the evolving needs of learners and adapt to changing educational landscapes, they encounter a myriad of challenges that must be navigated. From logistical hurdles such as limited access to technology infrastructure and resources to pedagogical considerations such as ensuring the quality and effectiveness of digital learning experiences, the journey towards integrating TEL is fraught with obstacles. Moreover, the rapid pace of technological innovation presents its own set of challenges, as educators must grapple with staying abreast of emerging trends and technologies while maintaining a focus on pedagogical principles and educational best practices (5).

The implementation of a TEL in a learning environment necessitates a novel approach that significantly impacts pedagogical and instructional design (6). Consequently, alternative teaching methods and engaging learning activities are required to effectively facilitate learning in this context (7). This adaptation entails that educators must adjust their instructional approaches while upholding consistent learning standards (8, 9). Moreover, since the efficacy of teaching is partially contingent upon educators' proficiency in utilizing technology (7), they must actively acquire technological skills and have opportunities for experimentation and evidence-based evaluation (6, 8).

Another challenge inherent in incorporation of TEL in teaching sessions is the increased demand for coordination from educators (10). In this new instructional setting, educators must navigate between physical and virtual spaces, executing various operational tasks within the teaching and learning platform. Consequently, educators experience heightened cognitive load, characterized as hyper-zoom or hyper-focus (7, 10).

Nonetheless, the prevalence of limited digital proficiency presents a significant impediment that compromises the efficiency of teaching among faculty members. This challenge is echoed in the findings of several studies (11).

In the context of developing countries such as Pakistan, the utilization of TEL has demonstrated notable advancements; however, several impediments persist, impeding the efficacy of Technology integration within education (12). Research conducted within the Pakistani educational milieu indicates that students frequently exhibit enhanced performance on digital platforms compared to traditional methods (13). Conversely, studies suggest a deficiency in the digital competence of educators concerning the development of pedagogically sound lessons (14), notwithstanding the pivotal role of teachers in effectively integrating TEL within the classroom environment (15). Educators have delineated significant hurdles in the implementation of e-learning initiatives in Pakistan, many of which resonate within the domain of online medical education. These obstacles encompass deficiencies in instructional design, recurrent power outages, faculty resistance to embracing novel teaching methodologies, and adherence to entrenched sociocultural norms (16).

Hence, it is incumbent upon higher educational institutions to prioritize the organization of training sessions aimed at cultivating digital competence among teachers (17).

Objectives

The primary objective of this project encompasses several key elements aimed at enhancing the utilization of Technology-Enhanced Learning (TEL) among faculty in health professions education. Firstly, the article seeks to assess the baseline knowledge and self-assessment of health professions educators regarding fundamental TEL components. This involved recognizing their existing understanding and proficiency in utilizing technology for educational purposes. Subsequently, the project aims to improve the teaching proficiency of these educators in delivering essential TEL components to undergraduate and graduate students. This enhancement was facilitated through the development and implementation of a personalized e-tutorial tailored to educate faculty members on the fundamentals of incorporating technology into their teaching methodologies.

Furthermore, this research intends to gather valuable feedback from health professions faculty regarding the usability of the e-tutorial and the challenges they encounter when integrating TEL into their instructional practices. This feedback can be instrumental in refining the e-tutorial and addressing any barriers faced by educators in adopting TEL effectively.

Aligned with these objectives, the project revolves around identifying strategies for leveraging technology to enhance instruction in resource-constrained environments. Additionally, it seeks to extract insights from the experiences of educators to inform effective faculty development initiatives, provide practical guidance applicable to similar educational contexts globally, and contribute to the formulation of improved policies and support mechanisms for

technology integration in education. Through these objectives, the project aims to foster advancements in health professions education by empowering educators with the necessary knowledge and tools to effectively utilize technology in their teaching practices.

Methodology

Ethical considerations

Behavioral and Ethical Research Approval (BERA) guidelines for ethics were followed (18). To maintain the confidentiality of data, all the participants were given codes for quantitative data collection, and questionnaires were tagged with the same codes. Google forms were used for collecting quantitative data. Participants were allowed to skip the demographic details. The Studies involving human participants were reviewed and approved by the institutional review board of National University of Medical Sciences (NUMS). Written informed consent to participate in this study was provided by the participants. Consent was taken from each participant both for the quantitative and qualitative data. Researcher bias was controlled as three researchers were involved in the thematic analysis of qualitative data. A new email account was used for collecting google form responses.

Methods

It is an interventional study having both quantitative and qualitative portions. A team consisting of one biostatistician, and three medical educationists, conducted this study. Team identified key components of E-curriculum design and delivery through literature search, with a particular focus on instructional and assessment strategies. One member of the Design and Technology (DT) department of the university was involved in training researchers for creating a customized e-tutorial on LMS (open this up) tailored for faculty training. In the initial phase, the DT personnel provided training to the medical educationists who were developers of this tutorial, on all aspects of Moodle, including synchronous and asynchronous teaching features like Big Blue Button and assessment process like Multiple Choice Questions (MCQs), and Short Answer Questions (SAQs), so that they would find it easy to develop the e tutorial.

Sampling

Forty volunteering Health Professions Educators, of various departments of the university were recruited in the study, they all gave the consent as well. All were assistant professors and above, with more than 5 years of teaching experience.

Data collection

Data was collected in two phases. A survey concentrating on participants' knowledge and comprehension regarding the appropriate utilization of available technologies was distributed using Google Forms before the training. The questionnaire distributed had 6 main domains with few subdomains to which participant response was required. For designing questionnaires extensive literature search was done, Questionnaire was designed based on the findings of research. First draft was sent to six experts from the field of technology and medical education. The suggestions were incorporated and sent again to experts for reconfirmation before finalization of the questionnaire. Pilot testing was done with limited number of participants.

The Second phase of data was collected through a focus group discussion (FGD) once the educators had completed the online tutorial at their convenience within a stipulated time. FDG conducted with a gap of 2 months after e-tutorial with the understanding that faculty had utilized this e-tutorial experience in their teaching learning activities as well.

The formulation of the focus group guide involved a comprehensive review of relevant literature and consultation with experts in the field in addition to some input linked to the e-tutorial. Validation of the guide was achieved through soliciting input from these experts. Subsequently, participants were invited to engage in the focus group discussion at a predetermined date and time. Out of a total of 40 potential participants, eight faculty members representing multiple departments, provided consent to take part in the discussion and were available during the data collection session. To uphold confidentiality, participants were assigned unique codes. The interaction between three researchers and the participants was audio-recorded to facilitate accurate documentation. The diverse perspectives expressed by participants contributed significantly to the depth of data collected for the project. Following data collection, transcription was conducted by the Principal Investigator. To ensure rigor and reliability, the transcribed data was independently reviewed by the Principal Investigator (PI) and two additional researchers (AR) who were not affiliated with the project as authors consolidating the triangulation process and enriching the overall validity of the findings. Subsequent thematic analysis was conducted by the same team of PI and two ARs to extract key themes from the qualitative data. This step was implemented to mitigate potential researcher bias and ensure methodological integrity.

Data analysis

Quantitative data was analyzed through SPSS version 23. Descriptive analysis was done. Qualitative data was analyzed through thematic analysis.

Designing of e-tutorial

The Learning Management System (Moodle) was utilized as the interface for the e-tutorial. The e-tutorial was structured such that content progressed from basic to advanced and simple to complex. However, once initiated, participants could progress through the tutorial at their own pace but within a 30 day period. Each subsequent step would unlock only when the participant had completed the required readings, watched videos, accessed other learning resources, and successfully passed a small MCQ test (See Appendix 1). Upon completion of the entire course, participants could download their E-certificates.

To facilitate understanding, the researchers created brief screen recordings demonstrating how to use various tools like Big Blue

TABLE 1 Frequency of participants opting different responses about "distance learning."

Option	Number of responses with percentages (*N* = 40)
Another name for E-learning	14 (35)
(Use of technology to update student's knowledge through online learning)	18 (45)
Use of technology to address distance between student and teacher	8 (20)

TABLE 2 Frequency of participants opting different responses about e-learning.

Option	Number of responses with percentages (*N* = 40)
(Simply a broadcast of documents in electronic format to students via the Internet)	2 (5)
Another name for distance learning	6 (15)
An online communication between the teacher and the student which can be used in a classroom or an online setting	32 (80)

TABLE 3 Frequency of participants opting different responses about "self study."

Option	Number of responses with percentages (*N* = 40)
Study of topic as directed by teacher and is time-bound	5 (12.5)
(Non-timetabled study hours spent outside the classroom for learning purposes, e.g., for assignments, group work, class test)	35 (87.5)
A scheduled time to study within a classroom for learning purposes	0

TABLE 4 Frequency of participants opting different responses about "synchronous teaching."

Option	Number of responses with percentages (*N* = 40)
(Instructions are provided on the spot, as in face to face teaching)	38 (95)
There is defined time limit given by teacher to submit responses.	2 (5)
There is time gap between the instructions provided and response of the learners	0

Button and design MCQs and SAQs on Moodle. Additionally, they provided YouTube links showcasing teaching and learning e-strategies such as voice over presentations, the utilization of screen recordings and use of software and apps. Relevant scholarly articles and excerpts were uploaded at relevant steps of the e-tutorial, to enhance participant understanding and reinforce concepts. Following were the sections of the e-tutorial; details of which are given in Appendix 1

a Preamble
b Wishlist of designing an online course
c Snapshot (Table of specifications)
d Dynamic and real time delivery of content
e Teaching at your pace
f Quality check for learning
g New tools

Results

Quantitative results

The Questionnaire had three parts. The First part focused on the participants' understanding of different terminologies related to Technology Enhanced Learning. Each question was of the selected response type. The Second part was a self-assessment consisting of questions on competent use of different e-learning tools. The Third part inquired about participants' viewpoints regarding formal inclusion of e-learning in the curriculum.

Collectively, the survey results indicated that participants in this study generally recognized the importance of technology-enhanced learning but displayed varying levels of understanding regarding key terminologies. While a majority associated "Distance Learning" with technology-enabled knowledge updating, there was a notable percentage considering it as another term for "E-Learning." Additionally, participants demonstrated an understanding of "E-Learning," as online communication between teachers and students. In terms of self-study, participants overwhelmingly favored the option of "non-timetabled self-study" outside the classroom. However, none chose "scheduled classroom study."

Regarding teaching methods, synchronous teaching, characterized by real-time instructions, was the preferred approach, while asynchronous teaching with a time gap between instructions and responses was less favored. Participants exhibited a spectrum of knowledge and experience with online teaching, with many feeling they had average to good proficiency but still required some guidance.

These findings emphasize the need for clarity in use of the correct nomenclature in technology-enhanced learning and highlight the importance of professional development to enhance educators' digital competence. Following tables; Tables 1–11 summarize the results of the survey questionnaire.

Tables 1–6 are giving the frequency as well as percentages of responses in each dimension.

Table 7 shows the mean rating and mode of responses while Table 8 summarizes the view points of the participants regarding inclusion of technology enhanced teaching in the curriculum. Overall results shows that participants seem reluctant in making online teaching as a regular part of students' teaching, they preferred using it as an additional mode.

Table 9 summarizes the categories of academic issues mentioned by participants and the number of participants who mentioned each

TABLE 5 Frequency of participants opting different responses about "asynchronous teaching."

Option	Number of responses with percentages (*N* = 40)
(There is time gap between the instructions provided and response of the learners)	38 (95)
Instructions are provided on the spot, as in face-to-face teaching	2 (5)
Both teacher and student must be online at the same time	0

TABLE 6 Frequency of participants opting different responses about "knowledge and experience of online teaching."

Option	Number of responses with percentages (*N* = 40)
Poor - No knowledge & no practical experience of the subject	2 (5)
Fair - Some knowledge but no practical experience of the subject	12 (30)
Average - Knowledge and practical experience but require some guidance	17 (42.5)
Good - Knowledge and practical experience, do not require guidance	6 (15)
Excellent - Have knowledge & practical experience with the ability to start a new initiative	3 (7.5)

TABLE 7 Mean rating of responses of questions related to participants' perceptions regarding their own competencies and expertise.

Question	Mean rating
Using technology and available software for designing an online course	3.52
Knowledge of all elements of the curriculum that should be included in an online course	3.65
Designing a synchronous teaching session (Real-time)	3.65
Designing an asynchronous teaching session (preparing a session)	3.55
Designing online assessment for students	3.25
Conducting a synchronous teaching session (Real-time)	3.35
Conducting an asynchronous teaching session (prepare and upload)	3.45
Conducting student assessment online	3.25
Providing feedback to students online	2.65
Uploading learning resources on a web portal	3.6
Google classroom	2.85
Zoom	2.75
Microsoft teams	2.975
WhatsApp	2.725
Moodle	3.15

Likert scale questions where 5 means excellent and 1 means poor.

TABLE 8 Mean rating of responses of participants about their willingness for including online teachings.

Statement	Mean (average) rating
Online teaching should be made part of regular student teaching	2.95
Online teaching should be used in addition to face-to-face teaching sessions	3.65
I will use online teaching to complement my face-to-face teaching even after COVID threat is over	2.65

issue. Most common issue highlighted by the participants was "Lack of students' active participation during teaching sessions."

Table 10 displays the categories of technical issues mentioned by participants and the number of participants who mentioned each issue. Poor connectivity is the most frequently mentioned issue.

Table 11 summarizes the categories of administrative issues mentioned by participants and the number of participants who mentioned each issue. The absence of an online teaching policy is the most frequently mentioned administrative issue.

Qualitative results

The themes that emerged in focus group discussion can be summarized in the Table 12.

The qualitative results can be explained with the help of Figure 1.

Understanding of terminologies related to TEL

In the context of the focus group study, participants were queried about their comprehension of terminologies pertinent to technology-enhanced learning, including synchronous learning. Post-engagement with an e-tutorial, participants reported an enhanced understanding of key terms such as synchronous and asynchronous learning, distance learning, and e-learning.

The participants expressed a heightened awareness of the significance of acquiring knowledge in these terminologies for a more profound grasp of online teaching strategies and pertinent literature related to e-learning. Notably, Participant 8 articulated this shift in perception, stating, "If you ask me, I never gave any significance to these terms before this training on the e-portal; now I can definitely say that I know for sure what these terms mean."

These findings underscore the efficacy of targeted e-tutorial interventions in elucidating complex terminologies associated with

TABLE 9 Frequency of responses of participants regarding academic issues.

Academic issues	Number of participants
Lack of effective assessment strategies	8
Lack of students' active participation during teaching sessions	12
Poor adaptability of students to online teaching	6
Poor adaptability of teachers to online teaching	2
Lack of courses/content availability	1
Lack of faculty enthusiasm during teaching sessions	1
Any other (unspecified academic issues)	3
None (no specific academic issues mentioned)	7

TABLE 10 Frequency of responses of participants regarding technical issues.

Technical issues	Number of participants
Poor connectivity	21
Non-availability of training program prior to the launch of online teaching	10
Any other (unspecified technical issues)	4
Non-availability of campus management system (LMS/CMS)	3
None (no specific technical issues mentioned)	2

technology-enhanced learning, thereby contributing to participants' broader comprehension of the subject matter. The acknowledgement of the newfound importance of these terms signifies a positive outcome in terms of knowledge acquisition and contextual understanding.

Benefits of e-tutorial training

In response to inquiries regarding their acquired knowledge from the e-tutorial, participants articulated a comprehensive understanding of various components intrinsic to e-learning and e-curriculum. This newfound knowledge encompassed insights into online learning platforms, exemplified by Moodle, and its multifaceted functions, including assessments, quizzes, and the creation of voice-over presentations.

Participants underscored the transformative impact of the training, asserting that it equipped them with innovative teaching tools such as screen recordings and voice-over presentations. The structured design of the e-portal, coupled with the accessibility of resources, emerged as pivotal factors facilitating their learning experiences.

TABLE 11 Frequency of responses of participants regarding administrative issues.

Administrative issues	Number of participants
Scheduling issues of online teaching sessions	7
Absence of online teaching policy	8
Mal distribution of faculty workload	5
Lack of Interdepartmental coordination	6
Any Other (unspecified administrative issues)	5
Absence of designed faculty time	3
Absence of accountability and record-keeping	2
Faculty resistance	1
None (no specific administrative issues mentioned)	3

Participant 3 elucidated, "I think my E teaching has systemized after getting trained through this e portal, like now I know the components of a curriculum that is delivered through e-learning, the requirements and the assessment strategies." This statement underscores the tangible impact of the e-tutorial on the organization and structuring of the participant's electronic teaching methods.

Participant 5 corroborated these sentiments, stating, "Before that training on the portal, we did not have any knowledge about any e-learning platform or even about Moodle. Now we are using Moodle to manage our e-learning, and the portal helped us a lot in knowing different functions like assessments and quizzes and presentations upload." This acknowledgment highlights the pivotal role of the e-tutorial in introducing participants to previously unfamiliar e-learning platforms and subsequently enhancing their utilization of Moodle for effective e-learning management.

Improved confidence

Following their participation in the e-tutorial, participants conveyed an enhanced sense of confidence in orchestrating online teaching sessions and adeptly employing diverse tools for online learning. This newfound assurance extended to their proficiency in conducting both synchronous and asynchronous teaching sessions, as well as in the nuanced tasks of designing and uploading e-assessments, coupled with the provision of constructive feedback.

Participant 6 elucidated on the impact of the training, stating, "I will specifically comment on the assessment part; while using Moodle, we had to send our material to the IT department and request them to upload it, but now we are confident and comfortable in doing both." This remark signifies a tangible empowerment regarding the independent management of e-assessment processes, a capability acquired through the e-tutorial.

Similarly, Participant 4 expressed a preference for synchronous learning and acknowledged the added allure brought about by e-learning tools, remarking, "I think I like synchronous learning more, but yeah, the e-learning tools made it more interesting, and the e-tutorial helped us a lot." This sentiment underscores the positive

TABLE 12 Qualitative results showing themes, codes and examples of relevant quotes.

S.no	Theme	Codes	Quotes
1.	Understanding of Terminologies related to TEL	Familiarity	"If you ask me, I never gave any significance to these terms before this training on the e-portal; now I can definitely say that I know for sure what these terms mean."
		significance	
		Readiness for future	
		Relevance	
2.	Benefits of e-tutorial training	Knowledge of components	"I think my E teaching has systemized after getting trained through this e portal, like now I know the components of a curriculum that is delivered through e-learning, the requirements and the assessment strategies."
		E learning platforms	"Before that training on the portal, we did not have any knowledge about any e-learning platform or even about Moodle. Now we are using Moodle to manage our e-learning, and the portal helped us a lot in knowing different functions like assessments and quizzes and presentations upload."
		Functions of Moodle	
		Synchronous learning tool	
		Access, ease and availability	
		Organized learning	
		Back up data	
		Made work easy	
		Multiple tools and functions	
3.	Improved confidence	Confidence	"I will specifically comment on the assessment part; while using Moodle, we had to send our material to the IT department and request them to upload it, but now we are confident and comfortable in doing both"
		Enjoyment	
		Comfort	
		More interesting	
		Suitable and effective	
4	Problems faced during implementation of online teaching	Engagement issue	"The chances of cheating have increased in online teaching." "Preparing learning materials that can engage students for online teaching definitely needs more time."
		Increased cheating	
		Lack of policies	
		Lack of SOP for the students	
		Lack of feedback	
		Lack of training	
		Lack of expressions /body language	
5.	e-tutorial value in addressing issues	Training done	"I think the training of the portal equipped us to cater for *our lack of* knowledge and build our preparedness, but it cannot help technical issues like what to do when there are weak internet signals. Yes, we can use a synchronous tool for that matter, but we still need to look after such issues."
		Preparedness	
6.	Propositions for Improvement	Technical training	"Assessment tools should be improved, and training should be there."
		Detailed training	
		Improved tools	
7.	Preparedness for future situations	Hybrid lessons	"It should not be like that we are on campus and teaching in person, we forget all the training. These trainings should go parallel, and lessons should also be hybrid."
		Training on other LMS	

impact of the e-tutorial not only in fortifying confidence but also in rendering the learning process more engaging through the incorporation of innovative tools.

Problems faced during implementation of online teaching

During inquiries into the challenges encountered during the implementation of e-learning, participants identified several significant issues, notably technical difficulties such as weak internet signals, concerns about cheating during assessments, and the perceived necessity for more time to prepare learning resources for online teaching.

Participant 8 underscored the escalating risk of academic dishonesty in online teaching, stating, "The chances of cheating have increased in online teaching." Participant 4 emphasized the time-intensive nature of crafting engaging learning materials, noting, "Preparing learning materials that can engage students for online teaching definitely needs more time." Participant 2 further articulated

the time constraints faced in a fast-paced working environment, particularly in the creation of voice-over presentations for online sessions.

The lack of established policies and standardized operating procedures (SOPs) emerged as another major hurdle in effective e-learning implementation, as highlighted by Student 5 and endorsed by Student 6. They noted the importance of faculty preparedness, which was addressed to some extent through the use of the portal, but stressed the need for policies and SOPs, especially for students.

Participants 2 and 3 expressed concerns about student attitudes, noting a casual demeanor, reluctance to open cameras, and a perceived lack of seriousness during online classes. This aspect, coupled with the absence of policies, hindered the effectiveness of e-learning.

Additionally, participants voiced a need for further training on providing feedback and engaging students effectively. Participant 3 proposed incorporating components in the e-tutorial focusing on learner engagement and effective feedback. Participant 7 identified student engagement as a significant challenge. Participants collectively emphasized that body language, a crucial element in live teaching, was not adequately addressed in online settings.

In conclusion, the identified challenges encompass technical issues, time constraints, the absence of policies and SOPs, and difficulties related to student engagement. The participants' insights underscore the multifaceted nature of challenges inherent in the effective implementation of e-learning, necessitating comprehensive solutions and additional training components to address these concerns.

e-tutorial's value in addressing issues

When questioned about the efficacy of the e-tutorial in addressing previously mentioned challenges, participants acknowledged the role of the e-portal in enhancing their preparedness and knowledge. However, they noted that certain issues, such as technical challenges, cheating prevention, measurement of student understanding, and student engagement, were inadequately addressed by the e-tutorial.

Participant 1 recognized the training's effectiveness in addressing knowledge gaps and building preparedness but highlighted its limitations in dealing with technical challenges. Specifically, the participant noted, "I think the training of the portal equipped us to cater for lack of our knowledge and build our preparedness, but it cannot help technical issues like what to do when there are weak internet signals. Yes, we can use a synchronous tool for that matter, but we still need to look after such issues."

Concerns about cheating prevention were expressed by Participant 1, who stated, "I am still confused on how to cater for cheating among students." This reflects a perceived gap in the training's coverage of strategies to address academic dishonesty in an online learning environment.

Participant 2 pointed out the disadvantage of lacking visual cues such as body language in e-learning, making it challenging to gauge student understanding. The participant remarked, "Disadvantage is that the body language of students, expressions were not there in e-learning. I could not guess whether they are understanding or not, so could not measure the outcome. This issue is not catered in training through the e-portal."

In summary, while participants acknowledged the benefits of the e-tutorial in enhancing their preparedness and knowledge, they identified specific challenges that were not adequately addressed, particularly in the realms of technical issues, cheating prevention, and measuring student understanding in an online context. These insights highlight the need for a more comprehensive approach to training that encompasses a broader range of challenges associated with e-learning.

Propositions for improvement

When queried about potential improvements in the training, participants proposed enhancements in assessment tools, particularly advocating for the incorporation of subjective questions (Short Answer Questions - SAQs) in conjunction with multiple-choice questions (MCQs). Participant 2 emphasized this point, stating, "Assessment tools should be improved, and training should be there."

Additionally, participants recommended refining technical training and expanding options within MCQs to enhance the assessment process. This indicates a collective recognition of the pivotal role of assessment tools in gauging student understanding and proficiency in an online learning environment.

Another notable suggestion from the participants was to explore alternative Learning Management Systems (LMS) beyond the current platform, with a concurrent recommendation for training on these alternative platforms. Student 3 articulated this viewpoint, stating, "I think yes, but other LMS should be explored, and we should be trained on these LMS." This recommendation underscores a proactive approach to diversifying the technological infrastructure for online learning, potentially catering to varying instructional needs and preferences.

In summary, participants' suggestions for improvements in the training program revolve around the refinement of assessment tools, including the integration of subjective questions and exploration of alternative LMS, accompanied by corresponding training initiatives. These recommendations align with the participants' desire for a more comprehensive and versatile training experience in the realm of technology-enhanced learning.

Preparedness for future situations

When questioned about their preparedness for unforeseen situations in the future, participants expressed a sense of readiness but underscored the imperative of continuous training, particularly on hybrid teaching approaches.

Participant 3 articulated this perspective, stating, "It should not be like that we are on campus and teaching in person, we forget all the trainings. These trainings should go parallel, and lessons should also be hybrid." This assertion emphasizes the need for a sustained and concurrent approach to professional development, ensuring that training initiatives run in tandem with on-campus teaching activities. The call for hybrid lessons indicates an awareness of the evolving nature of educational practices and the necessity for educators to seamlessly integrate face-to-face and online teaching strategies.

In academic terms, the participants are advocating for an ongoing and integrated approach to professional development that aligns with the dynamic landscape of educational methodologies, with a specific

emphasis on hybrid teaching approaches. This perspective reflects a commitment to adaptability and continuous improvement in response to evolving educational needs.

Discussion

The discussion is structured around key domains emerging from both quantitative and qualitative results, with relevant references incorporated to provide a comprehensive analysis.

Knowledge and usability of TEL

The quantitative results of the study unveil a spectrum of understanding among participants regarding key terminology associated with technology-enhanced learning (TEL). Notably, 18 participants (45%) identified "Distance Learning" as "the use of technology to update students' knowledge through online learning." This points to a limited recognition of the role of technology in knowledge dissemination. It is noteworthy that this understanding might be influenced by the limited usage of online platforms and digital learning tools in traditional face-to-face settings.

A parallel study conducted by Gyampoh et al. (19) where faculty revealed a similar trend. More than 60% of participants in that study expressed feelings of incompetence and unfamiliarity regarding the requirements of using TEL in their teaching practices. These findings echo the sentiments of Petrusevich (20), emphasizing the importance of clarifying terminology in the context of online education for the effective design and delivery of online courses.

The identified lack of knowledge and limited usability can be effectively addressed through training and development initiatives for faculty. Ng and Lam's (21) study support this notion, highlighting that easy acceptance and behavioral adjustments were achieved through a well-thought-out plan. This plan, aligned with the institution's goals, gradually introduced e-elements in various training sessions. This approach not only addresses the challenges identified in the current study but also aligns with the insights from Govender and Govender (22), cited in Liu et al. (23), indicating that even teachers with access to technology and computer competency skills may struggle to integrate technology into their teaching practices. Proficient users of 21st-century technology, as emphasized by Manzano (24), are essential for the efficient integration of technology in education.

Problems faced during implementation of online teaching

The qualitative findings derived from the focus group discussion underscore the positive impact of the e-portal training on participants'

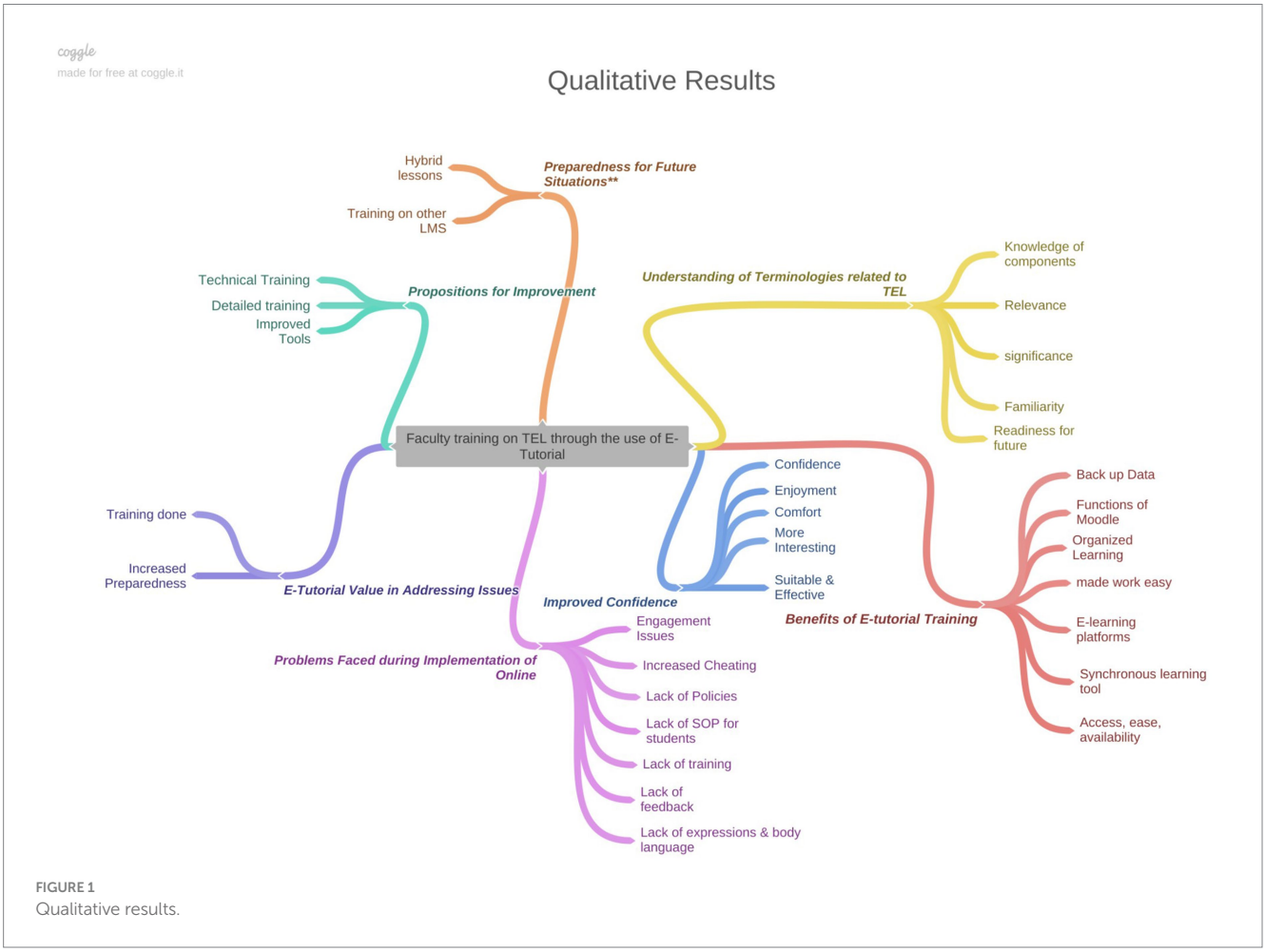


FIGURE 1
Qualitative results.

knowledge acquisition in various facets of e-learning. Participants reported gaining practical insights into the utilization of online learning platforms, such as Moodle, during the tutorial. The systematic design of the e-tutorial, complemented by the availability of resources and innovative teaching tools, significantly contributed to enhancing participants' confidence. This training not only increased their proficiency with digital tools but also empowered them to conduct both synchronous and asynchronous teaching sessions effectively. This aligns with the broader perspective that teacher training programs play a pivotal role in elevating digital competence within the higher education landscape (25).

Conversely, the study identified challenges during the implementation of online teaching, with technical issues, particularly poor connectivity, emerging as a prevalent problem. This observation resonates with existing research on the challenges of online education, particularly in developing countries where inadequate internet infrastructure poses a significant hindrance (26). Additionally, challenges related to student engagement and the measurement of student understanding underscore the importance of pedagogical strategies and tools that foster active participation and effective assessment in online environments (27).

The study findings also echo the broader challenges faced by educators in the online teaching landscape, including the need to engage students effectively, manage virtual classroom dynamics, adapt course content for online delivery, overcome technical issues, and ensure sufficient student participation (28). These challenges are compounded by variations in institutional support, policies, and educator attitudes, emphasizing the complexity of enhancing the quality of online education (19, 29–31).

Furthermore, participants' suggestions for improvement center on enhancing assessment tools and providing more robust technical training. The recommendation to incorporate subjective questions (SAQs) along with multiple-choice questions (MCQs) underscores the quest for more comprehensive assessments. Additionally, the proposal to explore a variety of learning management systems (LMS) and provide corresponding training aligns with the need for educators to adapt to diverse digital teaching environments (32). These recommendations emphasize the crucial role of continuous professional development for educators to remain abreast of evolving digital tools and teaching strategies (33).

Preparedness for future situations

The study illuminated participants' perceptions of preparedness for future uncertainties, particularly those precipitated by events like the COVID-19 pandemic. Participants acknowledged the significance of continuous training, specifically on various Learning Management Systems (LMS) and hybrid teaching approaches. This underscores the imperative for universities and educational institutions to invest in sustained faculty development initiatives, ensuring that educators remain adaptable in the face of evolving educational landscapes (34).

In the realm of medical education, the study suggests that administrators and educators must actively seek out innovative technologies to maintain the standards of medical education. It is imperative for medical educators to embrace emerging technologies that have the potential to shape the future of medical education (35–38). This adaptation to evolving technologies is crucial for enhancing the quality and effectiveness of medical education, especially in the context of unforeseen challenges and uncertainties.

Conclusion

To sum up, this research has yielded significant findings on the comprehension of technology-enhanced learning jargon by the participants, the influence of e-portal instruction on their digital proficiency, and the obstacles encountered when executing remote instruction. The results highlight how crucial it is for educators in the digital age to have clear language, efficient training, and continuous professional development. They also emphasize the necessity of resolving administrative, pedagogical, and technical issues in order to guarantee the success of online learning projects.

In general, this study adds to the ongoing discussion about how education is becoming more digital and how teachers are adopting more technology- enhanced teaching strategies. It emphasizes how crucial it is to give teachers the abilities and information required to succeed in digital learning environments.

Limitations

The sample size for focus group discussion was relatively small, and the participants were health professionals of only one institute; though from different disciplines, which may limit the generalizability of the findings.

Additionally, the study did not investigate the long-term impact of the training on participants' teaching practices.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

BERA guidelines for ethics were followed [Freedman et al. (18)]. To maintain the confidentiality of data, all the participants were given codes for quantitative data collection, and questionnaires were tagged with same codes. Google forms were used for collecting quantitative data. Participants were allowed to skip the demographic details. The Studies involving human participants were reviewed and approved by the institutional review board of National University of Medical Sciences (NUMS). Written informed consent to participate in this study was provided by the participants. Consent was taken from each participant both for the quantitative and qualitative data. Researcher bias was controlled as three researchers were involved in the thematic analysis of qualitative data. A new email account was used for collecting google form responses.

Author contributions

NSa: Conceptualization, Writing – review & editing. SF: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Data curation. NSh: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Investigation. AR: Conceptualization, Project administration, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The handling editor MA declared a past co-authorship with the authors NSh.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2024.1342654/full#supplementary-material

References

1. Kirkwood A, Price L. Technology-enhanced learning and teaching in higher education: what is 'enhanced'and how do we know? A critical literature review. *Learn Media Technol.* (2014) 39:6–36. doi: 10.1080/17439884.2013.770404

2. Luengo V, Aboulafia A, Blavier A, Shorten G, Vadcard L, Zottmann J. Novel technology for learning in medicine In: N Balacheff, S Ludvigsen, T De Jong, A Lazonder, SA Barnes, L Montandon, editors *Technology-enhanced learning: Principles and products* Berlin: Springer (2009). 105–20.

3. Gallardo-Echenique EE, de Oliveira JM, Marqués-Molias L, Esteve-Mon F, Wang Y, Baker R. Digital competence in the knowledge society. *MERLOT Journal of Online Learning and Teaching* (2015) 11.

4. Nguyen T, Netto CL, Wilkins JF, Bröker P, Vargas EE, Sealfon CD, et al. Insights into students' experiences and perceptions of remote learning methods: from the COVID-19 pandemic to best practice for the future. *Front Educ.* (2021) 6:647986. doi: 10.3389/feduc.2021.647986

5. MacNeill H, Masters K, Nemethy K, Correia R. Online learning in health professions education. Part 1: teaching and learning in online environments: AMEE guide no. 161. *Med Teach.* (2024) 46:4–17. doi: 10.1080/0142159X.2023.2197135

6. Weitze CL, Ørngreen R, Levinsen K. The global classroom video conferencing model and first evaluations In: IM Ciussi and M Augier, editors. *Proceedings of the 12th European conference on ELearning: SKEMA business school, Sophia Antipolis France, 30–31 October 2013 (bind 2, s. 503–510)*. Reading, UK: Academic Conferences and Publishing International (2013)

7. Bower M, Dalgarno B, Kennedy GE, Lee MJW, Kenney J. Design and implementation factors in blended synchronous learning environments: outcomes from a cross-case analysis. *Comput Educ.* (2015) 86:1–7. doi: 10.1016/j.compedu.2015.03.006

8. Grant MM, Cheon J. The value of using synchronous conferencing for instruction and students. *J Interact Online Learn.* (2007) 6:211–26.

9. Lightner C. A., Lightner-Laws C. A. (2016). A blended model: simultaneously teaching a quantitative course traditionally, online, and remotely. *Interact Learn Environ*, 50, 304–15. doi: 10.1080/10494820.2013.841262

10. Ørngreen R, Levinsen K, Jelsbak V, Moller KL, Bendsen T. Simultaneous class-based and live video streamed teaching: experiences and derived principles from the bachelor programme in biomedical laboratory analysis In: A Jefferies and M Cubric, editors. *Proceedings of the 14th european conference on E-learning (ECEL 2015)*. UK: Academic Conferences and Publishing International Limited (2015). 451–9.

11. Kanwal F, Rehman M. Factors affecting e-learning adoption in developing countries–empirical evidence from Pakistan's higher education sector. *Ieee Access.* (2017) 5:10968–78.

12. Salam S, Jianqiu Z, Pathan ZH, Lei W. Strategic barriers in the effective integration of ICT in the public schools of Pakistan. In *Proceedings of the 2017 International Conference on Computer Science and Artificial Intelligence* (2017) 169–72.

13. Shehzadi S, Nisar QA, Hussain MS, Basheer MF, Hameed WU, Chaudhry NI. The role of digital learning toward students' satisfaction and university brand image at educational institutes of Pakistan: a post-effect of COVID-19. *Asian Education and Development Studies.* (2021) 10:276–94.

14. Farid S, Ahmad R, Niaz IA, Arif M, Shamshirband S, Khattak MD. Identification and prioritization of critical issues for the promotion of e-learning in Pakistan. *Comput Human Behav.* (2015) 51:161–71.

15. Oguguo BC, Nannim FA, Agah JJ, Ugwuanyi CS, Ene CU, Nzeadibe AC. Effect of learning management system on Student's performance in educational measurement and evaluation. *Educ Inf Technol.* (2021) 26:147183.

16. Farooq F, Rathore FA, Mansoor SN. Challenges of online medical education in Pakistan during COVID-19 pandemic. *J Coll Physicians Surg Pak.* (2020) 30:67–9. doi: 10.29271/jcpsp.2020.Supp1.S67

17. Akram H, Aslam S, Saleem A, Parveen K. The challenges of online teaching in COVID-19 pandemic: a case study of public universities in Karachi, Pakistan. *J Inf Technol Educ Res.* (2021) 20:263–82. doi: 10.28945/4784

18. Freedman E., Bedward J., Hazlehurst S., Piper H., Taylor C. M. (2008). *The 2008 BERA charter for research staff: Promoting quality conditions for conducting quality research.* (British Educational Research Association).

19. Gyampoh AO, Ayitey HK, Fosu-Ayarkwah C, Ntow SA, Akossah J, Gavor M, et al. Tutor perception on personal and institutional preparedness for online teaching-learning during the COVID-19 crisis: the case of Ghanaian colleges of education. *Afr Educ Res J.* (2020) 8:511–8. doi: 10.30918/AERJ.83.20.088

20. Petrusevich DA. Modern trends in the digitalization of education In: *Journal of physics: Conference series* Krasnoyarsk, Russian Federation: IOP Publishing (2020)

21. Ng RYK, Lam RYS. A mind-set changing project: preparing vocational and professional education and training (VPET) teachers with technology enhanced learning (TEL) and E-pedagogies In: *Technology in Education. Innovative solutions and practices: Third international conference, ICTE 2018, Hong Kong, China, January 9–11, 2018, revised selected papers 3*. Singapore: Springer (2018). 179–87.

22. Govender DW, Govender I. Technology adoption: A different perspective in a developing country. *Procedia Soc Behav Sci.* (2014) 116:2198–2204.

23. Liu SH, Tsai HC, Huang YT. Collaborative professional development of mentor teachers and pre-service teachers in relation to technology integration. *J Educ Technol Soc.* (2015) 18:161–72.

24. Manzano EC. Technological and pedagogical knowledge: its influence on teaching performance. *Int J Open Access Interdiscipl New Educ Discov ETCOR Educ Res Center.* (2023) 2:147–56.

25. Røkenes FM, Krumsvik RJ. Development of student teachers' digital competence in teacher education-a literature review. *Nordic J Digit Lit.* (2014) 9:250–80. doi: 10.18261/ISSN1891-943X-2014-04-03

26. Almajali D, Ai-Hammouri Q, Barakat S. E-learning through COVID-19 crisis in developing countries. *Int J Pharm Res.* (2021) 13:09752366. doi: 10.31838/ijpr/2021.13.01.732

27. Zarei S, Mohammadi S. Challenges of higher education related to e-learning in developing countries during COVID-19 spread: a review of the perspectives of students, instructors, policymakers, and ICT experts. *Environ Sci Pollut Res*. (2022) 29:85562–8. doi: 10.1007/s11356-021-14647-2

28. Vijaylakshmi M, Baligar P, Mallibhat K, Kavale SM, Joshi G, Shettar A. Transition from in-person learning to technology enhanced learning in engineering education: faculty challenges In: *2021 IEEE Frontiers in education conference (FIE)* USA: IEEE (2021). 1–5.

29. Chang CL, Fang M. E-learning and online instructions of higher education during the 2019 novel coronavirus diseases (COVID-19) epidemic In: *Journal of physics: Conference series* Krasnoyarsk, Russian Federation: IOP Publishing (2020).

30. Greener S, Wakefield C. Developing confidence in the use of digital tools in teaching. *Electr J E Learn*. (2015) 13:260–7.

31. Kruszewska A, Nazaruk S, Szewczyk K. Polish teachers of early education in the face of distance learning during the COVID-19 pandemic–the difficulties experienced and suggestions for the future. *Educ 3–13*. (2022) 50:304–15. doi: 10.1080/03004279.2020.1849346

32. Niebuhr V, Niebuhr B, Trumble J, Urbani MJ. Online faculty development for creating E-learning materials. *Educ Health*. (2014) 27:255–61. doi: 10.4103/1357-6283.152186

33. Amhag L, Hellström L, Stigmar M. Teacher educators' use of digital tools and needs for digital competence in higher education. *J Digit Learn Teach Educ*. (2019) 35:203–20. doi: 10.1080/21532974.2019.1646169

34. Ironsi CS. Navigating learners towards technology-enhanced learning during post COVID-19 semesters. *Trends Neurosci Educ*. (2022) 29:100189. doi: 10.1016/j.tine.2022.100189

35. Tabatabai S. COVID-19 impact and virtual medical education. *J Adv Med Educ Prof*. (2020) 8:140–3. doi: 10.30476/jamp.2020.86070.1213

36. Tabatabai S. Necessity of designing a national model of foresight-based policy-making in medical education. *Strides Dev Med Educ*. (2017) 14:1–2. doi: 10.5812/sdme.67446

37. Barakabitze AA, William-Andey Lazaro A, Ainea N, Mkwizu MH, Maziku H, Matofali AX, et al. Transforming African education systems in science, technology, engineering, and mathematics (STEM) using ICTs: challenges and opportunities. *Educ Res Int*. (2019) 2019:1–29. doi: 10.1155/2019/6946809

38. Boddy C. A rose by any other name may smell as sweet but "group discussion" is not another name for a "focus group" nor should it be. *Qual Mark Res Int J*. (2005) 3:248–55.

frontiers | Frontiers in Medicine

TYPE Original Research
PUBLISHED 10 July 2024
DOI 10.3389/fmed.2024.1350975

OPEN ACCESS

EDITED BY
Muhammad Azeem Ashraf,
Hunan University, China

REVIEWED BY
Jernej Zavrsnik,
Health Center dr Adolf Drolc, Slovenia
Samson Maekele Tsegay,
Anglia Ruskin University, United Kingdom

*CORRESPONDENCE
Yanhong Jin
✉ Jin_yanhong23@163.com

RECEIVED 22 January 2024
ACCEPTED 18 June 2024
PUBLISHED 10 July 2024

CITATION
Chen Q, Jin Y, Zhong L, Li Y, Fu L, Zhang W and Xu Q (2024) Application effect of the online and offline mixed education mode in nursing practice based on the SMCR communication model.
Front. Med. 11:1350975.
doi: 10.3389/fmed.2024.1350975

Application effect of the online and offline mixed education mode in nursing practice based on the SMCR communication model

Qian Chen[1], Yanhong Jin[2]*, Lixia Zhong[1], Yingying Li[1], Li Fu[1], Weiwei Zhang[1] and Qiuying Xu[1]

[1]Department of Intensive Care Medicine, Beijing Friendship Hospital, Capital Medical University, Beijing, China, [2]Department of Nursing, Beijing Friendship Hospital, Capital Medical University, Beijing, China

Objective: To explore the application effect of the online and offline mixed teaching mode in nursing practice teaching based on the Source Message Channel Receiver (SMCR) communication model.

Methods: By using the convenience sampling method, 15 nursing students who practiced their internship in the Department of Critical Care Medicine at Beijing Friendship Hospital affiliated to Capital Medical University for 4 weeks, from 1 April 2022 to 31 December 2023, were selected as the experimental group. A total of 16 nursing students who practiced in the same hospital in 2021 were selected as the control group. The control group used traditional teaching mode for teaching, and the experimental group used the online and offline teaching mode for teaching. The theoretical and practical achievements, competency, and teaching satisfaction of the two groups of nursing students were compared and analyzed after the internship.

Results: The theoretical knowledge, operational performance, competence of the nurses, and satisfaction with the teaching in the experimental group were higher than those of the control group ($P < 0.05$).

Conclusion: Based on the SMCR communication model, exploring the online and offline mixed teaching mode plays an important role in the teaching process of nursing practice, which can not only effectively improve the comprehensive performance of nursing students but also help to improve their satisfaction with teaching and has a positive impact on the cultivation of high-quality nursing talents.

KEYWORDS

nursing practice teaching, SMCR communication model, application effect, online, offline

1 Introduction

With the continuous development of the medical industry in China, the requirements for nursing job are getting higher and higher. Clinical nurses must not only have professional theoretical knowledge but also have strong practical abilities. Therefore, for clinical intern nurses, it is difficult to comprehensively improve their practical ability and comprehensive quality if only the traditional teaching mode is adopted (1). In recent years, with the continuous development of information technology, the traditional teaching

mode has been unable to meet the needs of teaching profession. Therefore, the hybrid teaching mode combining offline teaching and online teaching has become more and more popular in major universities. As a brand-new clinical teaching model, it can effectively improve the teaching effect, stimulate students' passion, and help to deepen the interaction between teachers and students. The online and offline mixed teaching mode is based on offline education, incorporates online question and answer (Q&A), uploads nursing teaching videos and materials to the online teaching platform, and carries out multimedia teaching to deepen the theoretical knowledge of intern nurses.

The Source Message Channel Receiver (SMCR) model is an information dissemination model proposed by communication scholar David K. Berlo based on Lasswel's research (2, 3), which is mainly used in the fields of sociology and psychology. The important contribution of the SMCR model is mainly reflected in two aspects: one is to clearly define the four basic components contained in the process of information dissemination and the other is to systematically analyze the key factors that affect the process and effect of information dissemination from different factors (4). The SMCR communication model divides the communication process into four elements: source, information, channel, and receiver, and clearly, and vividly depicts the conditions that affect the information, source, receiver, and channel in order to perform its communication function. Among them, information sources include communication technology, knowledge, attitude, social system, and culture; information includes content, symbols, structure, and composition; channels include various tools for disseminating information, such as sensory organs, light, sound transmission, and modern media such as newspapers, magazines, radio, movies, television, and telephones; receivers are influenced by roughly the same factors as sources, including communication techniques, knowledge, attitudes, social systems, and culture. In the current times, the SMCR model has shifted from being used in the process of information dissemination to explaining the process of educational dissemination. For the purpose of improving the quality of educational dissemination, it is necessary to analyze these four elements. In the process of dissemination in the field of education, the result of educational dissemination information is affected by four factors.

Therefore, to establish a new and efficient nursing practice education method, this study is based on the SMCR model and integrates the online and offline mixed teaching mode to better understand the input characteristics (i.e., source, message, channel, receiver, and destination) of nursing students. We hypothesized that this teaching model would produce better teaching effects and would have high application and promotion value.

2 Methods

2.1 Participants

By using the convenience sampling method, 15 nursing students who practiced their internship in the Department of Critical Care Medicine at Beijing Friendship Hospital affiliated to Capital Medical University for 4 weeks, from 1 April 2022 to 31 December 2023, were selected as the experimental group. A total of 16 nursing students who practiced in the same hospital in 2021 were selected as the control group. The inclusion criteria adopted were as follows: ① nursing students who were interns in the Department of Critical Care Medicine and ② those who provided informed consent and willingness to participate in this study. The exclusion criterion set was: nursing students who take leave for more than 1 week during the internship. The two groups of nursing students completed the nursing practice tasks in the Department of Intensive Care Medicine. There was no statistically significant difference between the two groups in terms of gender, age, and education background ($p > 0.05$), and the practice goals of the two groups were the same, based on the "Nursing Graduation Practice Handbook" for intern nursing students, including the teaching goals of basic nursing skills and the practice goals of the Department of Critical Care Medicine. Through the combination of theory and practice, nursing students can master various clinical critical care skills, cultivate and improve nursing students' clinical thinking ability, post-competency and communication skills, and so on, as well as encourage them to apply knowledge to clinical practice. The two groups are compared using the abovementioned criteria.

2.2 Interventions

The control group adopts the traditional teaching mode, and the critical care clinical teachers formulate the nursing student internship plan according to the internship content in the clinical practice outline of the college and adopt the one-to-one teaching mode to complete the internship tasks with the nursing students, that is, the traditional nursing practice mode. During the 4 weeks after the intern nurses entered the department, they received theoretical lectures on the department environment, relevant rules and regulations, precautions, knowledge, and skills of common diseases in the Department of Critical Care Medicine; received lectures on basic nursing operation techniques, tracheal intubation coordination techniques, common critical medical equipment usage techniques, along with other relevant techniques, and checked the interns' mastery on the next day.

On the basis of the control group and the previous theoretical model, the experimental group constructed an online and offline mixed education mode in nursing practice based on the SMCR communication model and implemented this clinical nursing teaching model. The details of the online and offline mixed education mode in nursing practice are as follows:

Formation of the research team: The research team is led by the chief nurse of the department, and the team members include the head nurse of each ward, the head teacher, and the backbone of nursing. The team constructs the teaching content and evaluation indicators according to the requirements of the full-time and specialist practice manuals, mainly including basic nursing skills, operation ability, specialist nursing operation, nursing document writing ability, language expression ability, nursing etiquette, and interpersonal communication ability. The person in charge of the project is the leader of the nursing profession in the Department of Critical Care Medicine. He is responsible for establishing the nursing practice education model, arranging for members to

participate in teaching and training regularly, and applying the constructed nursing practice model to the intern nursing students of the Department of Critical Care Medicine. In addition, the teaching inspection team is composed of three to four head nurses and responsible nurses, who inspect the teaching quality from time to time.

The online and offline mixed teaching mode in nursing practice based on the SMCR model (see Figure 1 for the framework) was conducted in this study. The specific operation procedures are as follows:

(1) The first step involves clarifying the qualifications of the information source and understanding the characteristics of the information sink. Clinical nursing teachers are the gatekeepers of information and the senders of teaching information. Teachers' attitudes, abilities, knowledge, and social and cultural backgrounds could affect the effectiveness of information transmission. This study requires clinical nursing teachers in the Department of Intensive Care Unit (ICU) to have: ① have a bachelor's degree or above; ② have a nursing title or above; ③ have more than 5 years of work experience in ICU; ④ have mastered language expression, organization and management, information collection and processing, interpersonal communication, and other teaching abilities; ⑤ have proficiency in basic nursing technical operations, specialized technical operations, and specialized theoretical knowledge in intensive care medicine; ⑥ have proficiency in the clinical application of nursing procedures; ⑦ have rich teaching experience and a correct and responsible teaching attitude; ⑧ be able to skillfully use various teaching methods; and ⑨ be able to master online teaching methods proficiently. When designing the study, the members of the research team first reviewed the general information about the candidate teachers' educational background and work experience. Then, five to six head nurses and primary nurses would be invited to anonymously evaluate these candidate teachers to ensure that the teachers who eventually undertook the teaching tasks met the above nine characteristics and qualifications.

The receiver is the receiver of clinical knowledge, mainly considering the acceptance ability and attitude of nursing students.

(2) The second step involves benchmarking information elements and refining the content of clinical courses. In the SMCR model, information is the central link of information dissemination, and the composition and structure of information content, symbols, and processing methods all affect the dissemination effect of information. Based on this dissemination effect, the focus of the research is on an online and offline mixed teaching mode, the composition and structure of which required that the content of the nursing practice course in the ICU be practical, complete, and close to the clinic; key and difficult points are highlighted; the content is complete; the goal is clear; the content of the online and offline courses is well-connected; the class schedule is reasonable; in terms of symbols and processing, PPT, paper materials and other pictures, text, video, audio, and other symbols used in the course are clear; quizzes, homework, exams, and other learning resources are abundant; and the scientific nature and difficulty of assessment and evaluation are appropriate. For example, regarding the production of online teaching videos, you should pay attention to the following points:

Appropriate duration: It is best to control the time of online video courses within 5–15 min, and the content should be as short and concise as possible. Rich in content: It is best to use some novel, suspenseful, and problem-based cases or means to attract students, and let students arouse interest in boring knowledge from time to time and learn while watching. Attract attention: Even in the same video course, the scene and tone must be changed frequently, including the tone of the teacher and teaching aids, so that students can further pay attention to knowledge according to different environmental factors. Improving motivation: It is necessary that the design of online video course content enhance students' learning confidence and maintain students' desire for success. For example, some challenging situations or practice questions can be set up, which could be announced by the teacher at the end of the video or after class to make them feel "extraordinary" in their abilities. Appropriate difficulty: The difficulty of the course should be appropriate, and it should be easy to understand so as to enhance the confidence of nursing students, allowing them to appreciate the value and joy of learning through short online videos. It is necessary to ensure that each test question is consistent with the content in order to completely engage the nursing students' vision, hearing, touch, and taste.

(3) The third step is to logically combine the channels. Students' five senses play an important role in knowledge exchange, such as visual perception for non-verbal communication, hearing for receiving and explaining information, touch for acquiring knowledge through behavioral contact, and so on. The main information in clinical nursing practice teaching is vision, hearing, touch, and smell, and the research is based on the characteristics of various course information to clarify reasonable and effective channels.

(4) The fourth step is the clinical practice development process. As the primary supervisor, the clinical nursing teacher is responsible for guiding the internship process one-on-one. Before the internship in the ICU, the clinical nursing teacher assesses the situation of the internship nursing students in the department, including their self-study attitude, self-study ability, communication skills, learning interest, online learning conditions, and so on. According to the characteristics of students, the clinical nursing teacher adjusts the content and methods of practice based on the nursing practice outline plan, provides online learning materials for nursing students in advance, and encourages nursing students to prepare course previews well in advance. Teachers conduct online live teaching in accordance with the weekly internship plan. Offline teaching takes place in conference rooms and ICU wards and adopts methods such as case teaching, group discussion, and bedside clinical nursing teaching.

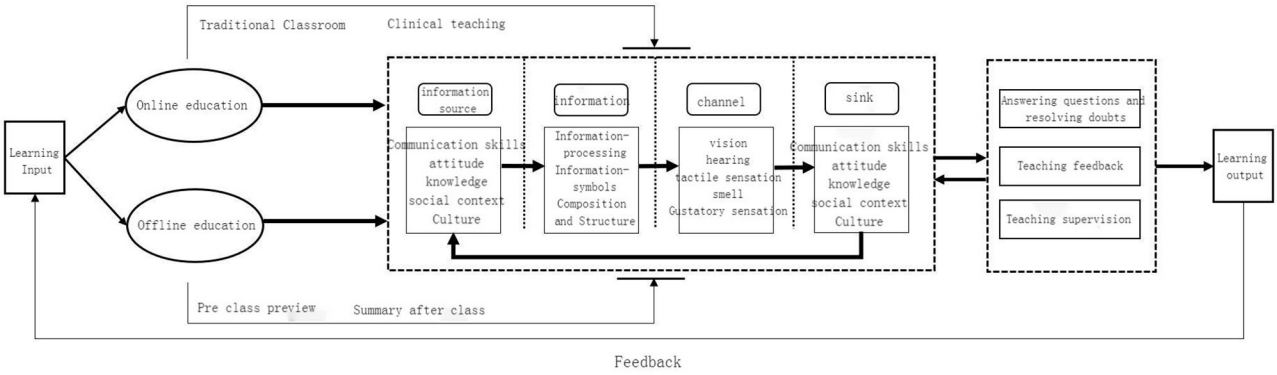


FIGURE 1
The framework for using the online and offline mixed teaching mode for nursing practice based on the SMCR model.

(5) The fifth step is providing feedback. After completing the teaching tasks of the day, the clinical nursing teachers fully understand the learning situation of the nursing students, answer their questions, listen to their suggestions, provide teaching feedback, and correct any shortcomings in the teaching method.

The clinical nursing teacher project team conducts both online live teaching and offline on-site learning activities. Some specific course content and elements are shown in Table 1.

2.3 Effect evaluation

Nursing interns in the experimental and control groups completed a theoretical assessment, a skill assessment, a nurse competency inspection, and an intern satisfaction survey. The theory assessment is a closed-book assessment method with a full score of 100 points, and the score indicates the pros and cons of their mastery of theoretical knowledge; the skill assessment is overlooked by the teacher responsible for the assessment, and nursing students randomly select basic operations and specialized operations, with 50 points for each operation. The total score is 100 points. The standard nursing operation assessment used in hospitals is adopted as the scoring standard. The higher the score, the better the students' clinical nursing practice performance; the nurse competency assessment uses a nurse competency scale. The ICU nurse competency survey scale compiled by Qiao Anhua has four dimensions and 58 items, including professional knowledge (14 items), professional technology (19 items), professional ability (20 items), and psychological traits (five items). The scale adopts the Likert 5-level scoring method, with a total score ranging from 0 to 232 points—the higher the score, the greater the level of victorious ability. A score of <116 is considered as a failure, 116–173 is a pass, and 174 indicates good performance. The scale has a content validity of 0.87, and the Cronbach's alpha coefficient is 0.93. Finally, the questionnaire survey was used to evaluate the satisfaction of nursing interns with the practice of teaching and learning. The evaluation content included the rationality of the practice mode, the quality of teaching in the practice mode, the quality of management of the practice mode, and a comprehensive evaluation of the practice mode. Scores ranged from 0 to 10—the higher the score, the higher the overall rating.

2.4 Statistical analysis

Statistical Package for the Social Sciences (SPSS) software, version 24.0, was used for data entry and statistical analysis. Measurement data are presented as $x \pm s$, and statistical inferences are made using the *t*-test. The test level was set at $\alpha = 0.05$, and a *p*-value of <0.05 was considered statistically significant.

3 Results

3.1 Comparison of practice theory and technical operation scores between the experimental and control groups

The results of the study revealed that nursing interns in the experimental group had higher theoretical and clinical nursing scores (93.07 ± 4.46 and 95.53 ± 1.85, respectively) compared to the control group (88.81 ± 5.58 and 91.56 ± 2.97, respectively). The group difference was statistically significant at a *p*-value of <0.05. The specific results are shown in Table 2.

3.2 Competence comparison of ICU nursing students between the experimental and control groups

The results of the nurse's competency inspection highlighted that nursing interns in the experimental group had higher total, professional knowledge, and professional technical scores (133.27 ± 9.95, 32.20 ± 3.00, and 44.60 ± 4.69, respectively) compared to the control group (122.88 ± 7.293, 28.38 ± 3.24, and 41.50 ± 2.76, respectively), with a statistically significant difference

TABLE 1 Contents and elements of online and offline mixed modes of nursing practice education in critical care medicine based on the SMCR communication model.

Teaching week	Course information		Online teaching time	Teaching form	Channel	Whether the teacher has the communication technology	Whether the course symbol is appropriate and reasonable	Whether the students are interested	Whether the students are qualified to study
	Curriculum theory knowledge	Curriculum practice technology							
First week	Department-related system and internship requirements	On-site introduction and familiarity with the environment	1 h	Live broadcast teaching and offline ward rounds	Visual and auditory	√	√	√	√
	Basic knowledge of common medical instrument use in the ICU	Field learning of common medical instruments (infusion pump, injection pump, nutrition pump, and glucose meter)	1 h	Live broadcast teaching and offline operation	Visual and auditory	√	√	√	√
	Routine care for common diseases in the ICU	Common ICU physical examination techniques	1 h	Live broadcast teaching and offline ward rounds	Vision, hearing, touch, and smell	√	√	√	√
	Fixation and nursing points of common pipelines in the ICU	Practical operation of pipe fixation	1 h	Live broadcast teaching and offline operation	Vision, hearing, and touch	√	√	√	√
Second week	Identification and nursing of abnormal heart rhythms	ECG monitoring technology	1 h	Live broadcast teaching and offline operation	Vision, hearing, and touch	√	√	√	√
	Care of patients with cardiac arrest	Cardiac electrical defibrillation technique	1 h	Live broadcast teaching and offline operation	Vision, hearing, and touch	√	√	√	√
	Knowledge of common ICU	On-site study of rescue vehicle structure and drug list	1 h	Live broadcast teaching and offline operation	Visual, auditory	√	√	√	√
	Classification and establishment of the artificial airway	Tracheal intubation was performed in combination	1 h	Live broadcast teaching and offline operation	Vision, hearing, and touch	√	√	√	√
Third week	Basic knowledge of the ventilator	Installation of the ventilator line	1 h	Live broadcast teaching and offline operation	Vision, hearing, and touch	√	√	√	√
	Airway care for mechanically ventilated patients	The sputum suction technique via a breath tube for intubation	1 h	Live broadcast teaching and offline operation	Vision, hearing, and touch	√	√	√	√
	Airway temperature and dampness	Oral care techniques for critically ill patients	1 h	Live broadcast teaching and offline operation	Vision, hearing, and touch	√	√	√	√

(Continued)

10.3389/fmed.2024.1350975

TABLE 1 (Continued)

Teaching week	Course information		Online teaching time	Teaching form	Channel	Whether the teacher has the communication technology	Whether the course symbol is appropriate and reasonable	Whether the students are interested	Whether the students are qualified to study
	Curriculum theory knowledge	Curriculum practice technology							
	Chest physiotherapy	Practice of the chest physiotherapy method (vibration sputum detector)	1 h	Live broadcast teaching and offline operation	Vision, hearing, and touch	√	√	√	√
Fourth week	Management of the common alarms on the ventilator	Handling of the common alarms of the ventilator	1 h	Live broadcast teaching and offline ward rounds	Vision, hearing, and touch	√	√	√	√
	Knowledge of the prevention and control of common respiratory-transmitted diseases	Closed-type sputum suction technology	1 h	Live broadcast teaching and offline operation	Vision, hearing, and touch	√	√	√	√
	ICU hospital infection prevention, control, and management	Wear and take off hand hygiene and isolation clothes	1 h	Live broadcast teaching and offline operation	Vision, hearing, and touch	√	√	√	√
	Preventive measures for the “three tubes” infection	Venous blood collection and intravenous infusion technique	1 h	Live broadcast teaching and offline operation	Vision, hearing, and touch	√	√	√	√

10.3389/fmed.2024.1350975

TABLE 2 Comparison of internship theoretical achievements and technical achievements between the two groups.

Division of groups	Theoretical results	Operating results
Experimental group ($n = 15$)	93.07 ± 4.46	95.53 ± 1.85
Control group ($n = 16$)	88.81 ± 5.58	91.56 ± 2.97
t-value	2.335	4.439
p-value	0.027*	<0.001*

*$P < 0.05$.

between the two groups. The professional skills and psychological characteristics of the nursing interns in the experimental group were similar to those in the control group ($P > 0.05$). The specific results are explained in Table 3.

3.3 Comparison of interns' satisfaction with the teaching mode between the experimental and control groups

A questionnaire survey was conducted to assess the teaching satisfaction of interns, with the evaluation content including the rationality of the internship model, the quality of the teaching of the internship model, the quality of the management of the internship model, and the comprehensive evaluation of the internship model. The results exhibited that there were statistically significant differences between the scores of the experimental and control groups in all aspects ($P < 0.05$), and the scores of the experimental group were higher than those of the control group. The results are shown in Table 4.

4 Discussion

Nursing is a highly practical subject, and clinical practice teaching is an important component of cultivating nursing talents. Nursing content is characterized by abstraction, its complex anatomical structure, and many types of therapeutic drugs, making it difficult for nursing students to accurately understand and remember during the internship stage and apply the knowledge they have learned to clinical practice. Therefore, the selection of appropriate teaching methods for nursing practice has a great impact on improving the efficacy of nursing students' practice, cultivating clinical thinking ability, and improving teaching quality (5).

Due to the lack of emphasis on clinical teaching jobs in some hospital nursing departments, there is a lack of scientific and reasonable assessment of the teaching qualifications of teaching teachers. The uneven quality of teaching among some teachers has a direct impact on the clinical practice experience of nursing interns. Some teaching teachers do not have a deep and clear understanding of the teaching profession; they treat the nursing interns as if they were their own helpers, lack the sense of responsibility for the nursing interns, and do not provide clear guidance. Due to the lack of comprehensive and scientific evaluation after students enter the course, some teachers do not fully understand the students' theoretical knowledge, practical operation skills, and personality characteristics; as a result, they adopt a mechanized and repetitive teaching mode, which cannot obtain satisfactory teaching results. Due to the lack of teaching objectives and plans in clinical teaching jobs, some nursing interns are unable to clearly understand the content and skills that must be mastered during the internship stage after entering the department and instead passively follow the teacher's to learn, which limits their efforts to take subjective initiatives to completely engage in learning. Considering that medical students lack clinical practice experience and have a low level of cognition of the clinical nursing process and content, teachers with specific clinical experience should be entrusted to guide and assist nursing interns in completing the established clinical nursing tasks. In this process, the professional quality and teaching effectiveness of the teaching teachers have a direct effect on the improvement of nursing interns' clinical nursing level (6, 7).

In addition, nursing students entering clinical practice can master the disease characteristics and nursing methods of different specialties by rotating through different departments; however, in the actual teaching process, some teachers focus more on basic operations, making it impossible to fully understand and master the various characteristics of different specialties. In light of various problems in the clinical teaching process of nursing interns, as well as the need to cultivate nursing personnel who meet the clinical requirements, it is necessary to further optimize the clinical teaching profession.

The study found that, due to the lack of clinical nursing thinking and the ability of interns, coupled with insufficient nursing technology and communication skills, the interns could not quickly enter the nursing field. Therefore, with a view to improve the working ability of nursing students, it is necessary to collaborate with scientific teaching mode in clinical nursing to improving comprehensive ability and lay the foundation for their future participation in clinical nursing jobs. The traditional teaching mode focuses solely on teaching professional skills and provides less focus on training on intern's comprehensive skills and psychological quality, but the practice has shown that it is necessary to strengthen the teaching methods in all aspects, increase focus on training, pay attention to details, establish dynamic monitoring, and maximize teaching interaction as a way to improve the teaching effect of intern nursing students. In clinical nursing, trainee nursing students not only need to have solid theoretical knowledge but also strong practical skills.

As a brand-new teaching mode, the online and offline mixed teaching mode primarily uses the Internet to carry out education, which effectively promotes the development of nursing education. It offers several advantages, such as greater flexibility, unrestricted time, and location independence. The online and offline mixed teaching mode is an interactive one that allows students to gather the necessary information through the Internet to effectively solve the problems raised by themselves and teachers. This approach enables students to better grasp and understand the knowledge points and use them to enhance students' ability to discover, analyze, and deal with problems (8, 9) while also improving team awareness and self-learning awareness (10), thereby improving teaching effectiveness (11). In recent years, many colleges and universities have been competing to adopt online

TABLE 3 Comparison of ICU nursing students between the two groups.

Division of groups	Experimental group ($n = 15$)	Control group ($n = 16$)	t	p
Total points	133.27 ± 9.95	122.88 ± 7.293	3.331	0.002*
Professional knowledge	32.20 ± 3.00	28.38 ± 3.24	3.400	0.002*
Professional technology	44.60 ± 4.69	41.50 ± 2.76	2.226	0.031*
Specialized skill	43.13 ± 6.19	40.31 ± 5.26	1.370	1.818
Mental trait	13.33 ± 1.54	12.69 ± 1.30	1.262	0.217

*$P < 0.05$.

TABLE 4 Satisfaction of trainee nursing students with the model in the experimental group.

Division of groups	Rationality	Quality of teaching	Teaching efficiency	Management quality	Overall merit
Experimental group ($n = 15$)	8.20 ± 1.08	7.73 ± 0.46	7.80 ± 0.94	8.13 ± 0.83	8.87 ± 1.13
Control group ($n = 16$)	6.20 ± 1.10	5.92 ± 0.31	6.55 ± 0.81	6.96 ± 0.43	7.12 ± 1.12
t-value	4.521	5.376	4.712	3.859	4.512
p-value	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*

*$P < 0.05$.

and offline mixed teaching (12, 13), which has become the current trend (14).

Every teaching system can be regarded as an information dissemination system, and the online and offline mixed teaching mode is no exception. The SMCR model is used not only in the fields of psychology and sociology but also in educational dissemination as a means to explore and optimize. Focusing on the four dimensions of the SMCR model, this study optimizes it by integrating the online and offline mixed teaching mode and discusses its application effect. First, the teaching team on the source side serves as the source of information. In the process of nursing practice courses, there are many factors that influence the source of information. The source's attitude, knowledge, and experience, communication skills, and culture have a direct impact, indicating that the quality and impact of information dissemination bear the main responsibility (15). This study is led by the chief nurse, and the team members include the head nurses of each ward, the head teacher, and the backbone of nursing. A teaching team comprising outstanding members of each ward has been formed, a nursing practice education model has been established, and members have been scheduled to participate in teaching and training regularly to fully ensure the quality of information sources. Second, the message is the central part to information dissemination in the SMCR model, and the composition and structure of information content, symbols, and processing methods all have an effect on the dissemination effect of information: ① In terms of symbols, they can be verbal or non-verbal; auditory or visual; and meaningful or meaningless (3). The images, text, video, audio, and other symbols used in this research course, such as PPT and paper materials, are clear; learning resources, such as tests, homework, and examinations, are abundant; and the assessment and evaluation are scientific and difficult. ② In terms of content, for small-scale online courses, the practical content should be organically combined with technology and diverse face-to-face activities such as lectures, experiments, problem solving, project design in order to achieve different teaching objectives, teaching content, and learner characteristics (16). The composition and structure section requires that the content of the intensive care practice nursing practice course be practical, complete, and closely related to the clinic; important and difficult points are highlighted; the content is complete; the goal is clear; the online and offline course content is well-connected; and the class schedule is reasonable. ③ In terms of processing methods, the innovation of new course content for teaching should be considered the cornerstone of the entire nursing practice course. Teaching in nursing practice should be closely connected with student to improve targeted learning outcomes. When considering the influence of channels in the SMCR model, it involves five sensory factors: vision, hearing, touch, smell, and taste. Taste and smell do not play a big role in online teaching but vision and hearing do. However, vision, hearing, touch, smell, and taste all play a role in the offline teaching process.

In this study, the content of online and offline courses was well-connected, and the class schedule was manageable. The course's difficulty was appropriate and understandable, which boosted the confidence of nursing students. Additionally, it is crucial to ensure that the test questions are aligned with the content, ensuring that nursing students feel the value and joy of learning through short online video lessons in order to completely engage their senses of sight, hearing, touch, smell, and taste. Finally, this study found that strengthening teacher-student interaction, student-student interaction, student-media interaction, and teacher-media interaction can effectively promote teaching effects. After completing the online course, combined with the information platform, the teaching teacher can grasp the learning situation of the students at any time, adjust the course arrangement, set evaluation goals according to the platform's exercises, exchanges, homework, tests, etc., and form a learning situation analysis. At the same time, combined with offline practice, discussion, report, and evaluation, the teaching evaluation is finally formed, which lays the foundation for the course design of the next teaching cycle (17).

The results of this study depicted that the test scores, competencies, and teaching satisfaction of nursing students in the experimental group were better than those in the control group ($P < 0.05$). The reason for this is that online and offline hybrid teaching is a teaching method that combines both online and offline instruction, as well as one that spans time and space. Combining the benefits of online and real-world teaching and integrating people into teaching process can result in multi-element and multi-dimensional unified coordination, and students can repeat online learning. Teachers can also answer questions left by students. Students can study independently on the platform, and after completing homework and tests, teachers can answer and correct homework online, which significantly improves teaching quality and efficiency.

5 Conclusion

The online and offline mixed teaching mode based on the SMCR communication model can effectively improve the comprehensive performance and the overall level of nursing students in the process of nursing practice teaching, as well as the satisfaction of nursing students with teaching, and cultivate nursing students' learning ability, problem-solving ability, and clinical thinking ability so that their comprehensive quality can be substantially improved and the teaching effect is remarkable. These findings have important guiding significance and reference value for exploring diversified nursing teaching modes and cultivating high-quality nursing talents.

This study also has some limitations. First, the small sample size reduces test efficiency, resulting in no statistically significant differences between the experimental and control groups for some items. Second, due to the difficulty of sample inclusion, the control group used previously collected data and did not abide by the principle of random grouping. It is also worth noting that the SMCR model has inherent limitations. McGuire's theoretical framework of SMCR model guides the pre-production stage of formative research on the target audience, but this theory does not account for subtle changes in the process of practice based on the audience's acceptance of information. This result can lead to discrepancy in the expected teaching progress and the absorption and integration of knowledge by the actual audience. More teaching models combined with SMCR model will be explored in the future to further improve the quality of nursing education.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Beijing Friendship Hospital. Written informed consent was obtained from all participants. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

QC: Data curation, Formal analysis, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. YJ: Conceptualization, Data curation, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. LZ: Formal analysis, Methodology, Writing – original draft, Writing – review & editing. YL: Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing. LF: Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing. WZ: Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing. QX: Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. The project was supported by the 2021 Education and Teaching Reform Research Project of Capital Medical University (2021JYY307). Funding agencies did not play a role in study design, data collection, analysis and interpretation, or manuscript writing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. Macedo A, Mendes C, Candeias A, Sousa M, Hoffmeister L, Lage M. Validation of the nursing activities score in portuguese intensive care units. *Rev Bras Enferm.* (2016) 69:881–7. doi: 10.1590/0034-7167-2016-0147

2. Fawn K, Leslie DE, Don E, Donna LG. Exploring communication tendencies of program facilitators. *J Appl Commun*. (2019) 103:1415. doi: 10.4148/1051-0834.1415

3. Nanguo N, Li Y. *Educational Communication*. Beijing: Higher Education Press (2006).

4. Zheng Y, Ma S, Liu S. The path selection of MOOC construction from the perspective of SMCR model. *China Audio Vis Educ.* (2014) 64:36–41.

5. Su Q, Dai RX, Yang XH, Zhao WK. Application of situation-based PBL teaching in clinical practice teaching of cardiology department. *Contemp Med.* (2020) 26:177–8.

6. Jin LY, Zhang L, Zhang SY, Tian FY, Guo QY, Guo Y. Analysis of the effect of application of reversal class combined with CBL teaching method in ICU nursing practice teaching. *Health Vocat Educ.* (2021) 39:118–9.

7. WHO. *Global Standards for the Initial Education of Professional Nurses and Midwives [EB/OL]*. Available online at: https://www.who.int/publications/i/item/9789240033863

8. Wei C, Li S, Wei H. A study on the application of "On-line + off-line" mixed teaching model in clinical nursing teaching. *J Lanzhou Inst Educ.* (2020) 36:102–3.

9. Wang Y, Hu JH, Chi XH, Xie D, Wang YH. A practical study on the online-offline mixed teaching model of basic nursing courses. *High Med Educ China.* (2020) 59–60. doi: 10.3969/j.issn.1002-1701.2020.04.030

10. Ellström P. Four faces of educational organizations. *High Educ.* (1983) 12:231–41. doi: 10.1007/BF00136639

11. Li W. Application of on-line and off-line mixed teaching mode in basic nursing teaching in higher vocational colleges. *Modern Vocat Educ.* (2021) 194–5.

12. Du Y, Li SS, Guo XL, Cai Y, Xu ML. The application of online and offline mixed teaching in the practice teaching of nephrology. *Chin Med Rec.* (2021) 22:85–8.

13. Luo Y, Pan J, Mao H. Application of medical simulation teaching combined with PBL in nursing practice teaching. *Chin High Med Educ.* (2019) 123:125.

14. Guo PN, Zhang JY, Han XM, Qi CE. Application of on-line and off-line mixed teaching in stomatology teaching of clinical medicine specialty. *J Chifeng Coll.* (2021) 37:97–101.

15. Zheng Y, Li L. A study on the micro-curriculum design of primary and secondary school teacher training from the perspective of SMCR model. *China Audio Vis Educ.* (2017) 88–94.

16. Pan JX, Lin W, Huang HB, Liang JX Li LT, Cai LC. Application of "TBL + organ system-centered" offline + online mixed teaching model in medical education. *Electron J Trauma Emerg Med.* (2019) 7:104–6.

17. Zhang Y. Study on the multi-element mixed teaching strategy based on SMCR model. *J Sci Educ.* (2021) 123–5.

frontiers | Frontiers in Medicine

TYPE Original Research
PUBLISHED 07 August 2024
DOI 10.3389/fmed.2024.1425305

OPEN ACCESS

EDITED BY
Muhammad Azeem Ashraf,
Hunan University, China

REVIEWED BY
Melanie Stephens,
University of Salford, United Kingdom
Nadia Shabnam,
National University of Medical Sciences Rawalpindi, Pakistan
Rita Chhikara,
The NorthCap University, India

*CORRESPONDENCE
Yimin Zhang
✉ zhang_yimin@163.com

RECEIVED 29 April 2024
ACCEPTED 11 July 2024
PUBLISHED 07 August 2024

CITATION
Du Q, Wang D and Zhang Y (2024) The role of artificial intelligence in disease prediction: using ensemble model to predict disease mellitus.
Front. Med. 11:1425305.
doi: 10.3389/fmed.2024.1425305

The role of artificial intelligence in disease prediction: using ensemble model to predict disease mellitus

Qinyuan Du, Dongli Wang and Yimin Zhang*

Key Laboratory of Traditional Chinese Medicine Classical Theory, Ministry of Education, Shandong University of Traditional Chinese Medicine, Jinan, China

The traditional complications of diabetes are well known and continue to pose a considerable burden to millions of people with diabetes mellitus (DM). With the continuous accumulation of medical data and technological advances, artificial intelligence has shown great potential and advantages in the prediction, diagnosis, and treatment of DM. When DM is diagnosed, some subjective factors and diagnostic methods of doctors will have an impact on the diagnostic results, so the use of artificial intelligence for fast and effective early prediction of DM patients can provide decision-making support to doctors and give more accurate treatment services to patients in time, which is of great clinical medical significance and practical significance. In this paper, an adaptive Stacking ensemble model is proposed based on the theory of "error-ambiguity decomposition," which can adaptively select the base classifiers from the pre-selected models. The adaptive Stacking ensemble model proposed in this paper is compared with KNN, SVM, RF, LR, DT, GBDT, XGBoost, LightGBM, CatBoost, MLP and traditional Stacking ensemble models. The results showed that the adaptive Stacking ensemble model achieved the best performance in five evaluation metrics: accuracy, precision, recall, F1 value and AUC value, which were 0.7559, 0.7286, 0.8132, 0.7686 and 0.8436. The model can effectively predict DM patients and provide a reference value for the screening and diagnosis of clinical DM.

KEYWORDS

diabetes mellitus, disease prediction, machine learning, artificial intelligence, Stacking ensemble model

1 Introduction

Diabetes mellitus (DM) is a metabolic disease clinically characterized by chronic hyperglycemia, dyslipidemia and protein abnormalities, and other symptoms that increase the risk of morbidity and mortality, of which type 2 diabetes mellitus (T2DM) is a major public health challenge globally, and the assessment and management of this chronic disease carries a heavy economic burden (1–3). Worldwide, 537 million adults (aged 20–79) have diabetes (10%), and this number is expected to rise to 643 million by 2030 and 783 million by 2045 (4, 5).

Along with the rapid development of the intersection of artificial intelligence and medical diagnostics, machine learning (ML) has once become the most concerned topic among researchers, which can provide accurate predictive analysis of diseases, effectively identify high-risk factors as well as patients with high morbidity, and then provide accurate decision support for hospital administrators (6). By mining potential healthcare data through machine learning and constructing a novel DM prediction model, early warning of high-risk groups can be performed, and appropriate healthcare management can be taken to patients in advance, which can also provide certain decision support to doctors and reduce the rate of missed diagnosis and misdiagnosis (7).

Initially, researchers predicted DM through traditional machine learning and verified that random forest (RF) based on tree model has better prediction effect (8–12). Some researchers focused on the preliminary data processing to get a better DM prediction model using feature selection and data imbalance processing (13–15). Meanwhile, considering the influence of different factors on diabetes, researchers began to study the three aspects of age, gender and geography, and obtained a better prediction effect of the targeted population prediction model (16–18).

In recent years researchers began to consider the use of ensemble learning to predict diabetes and obtained diabetes prediction models that are superior to traditional machine learning (19, 20). In DM prediction, although machine learning is superior to traditional statistical methods, most of the research has focused on a single prediction model. Each prediction model has its advantages, disadvantages and limitations, and researchers use ensemble learning to combine the advantages of a single prediction model to build a more powerful ensemble model, of which the most effective Stacking ensemble model is gradually applied (21–23). From the perspective of single classification model, using Stacking ensemble model can solve the limitations of single classification model, but the selection of base classifiers and meta-learners of Stacking ensemble model has randomness (24).

To solve the above-mentioned problem, this paper follows the theory of "error-ambiguity decomposition" (25) and designs an adaptive Stacking ensemble model, which can further improve the prediction performance of DM model.

2 Materials and methods

In this paper, an adaptive Stacking ensemble model is designed and implemented on the DM dataset to predict DM patients, and the overall process framework is shown in Figure 1. Firstly, the DM dataset was normalized, followed by feature screening using the gradient boosting decision tree (GBDT) (26) feature selection method, and next the adaptive Stacking ensemble model was constructed by first adaptively selecting the base classifiers from n pre-selected models, and then traversing the models in the selection of meta-learners. The performance of the adaptive Stacking ensemble model, proposed in this paper was evaluated by five evaluation metrics: accuracy, precision, recall, F1 value and AUC value.

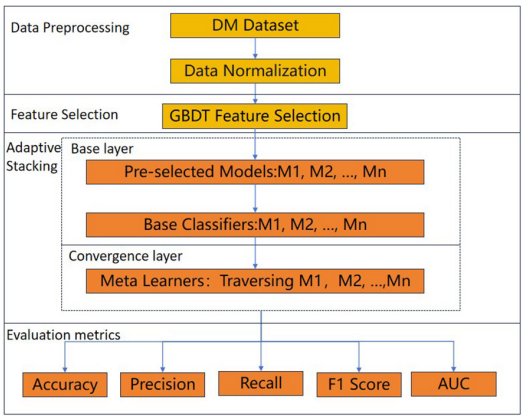


FIGURE 1
Prediction process flow chart.

TABLE 1 CDC's BRFSS2015.

ID	Feature	Detailed description
1	HighBP	High blood pressure
2	HighChol	High cholesterol
3	CholCheck	Had a cholesterol test within 5 years
4	BMI	Body mass index
5	Smoker	Smoker
6	Stroke	Stroke
7	HeartDiseaseor	Coronary heart disease or myocardial infarction
8	PhysActivity	Physical activity in the last 30 days
9	Fruits	Fruit 1 or more times per day
10	Veggies	Veggie 1 or more times per day
11	Alcoholic	Alcoholic
12	AnyHealthcare	Have any type of health insurance
13	NoDocbcCost	In the past 12 months, have you needed to see a doctor but were unable to do so due to cost?
14	GenHlth	Health status
15	MentHlth	Mental health status
16	PhysHlth	Health status
17	DiffWalk	Have severe difficulty walking or climbing stairs
18	Sex	Sex
19	Age	Age
20	Education	Educational level
21	Income	Income situation

2.1 Dataset

The dataset selected for this paper is a balanced dataset processed on CDC's BRFSS2015, which has the same proportion of

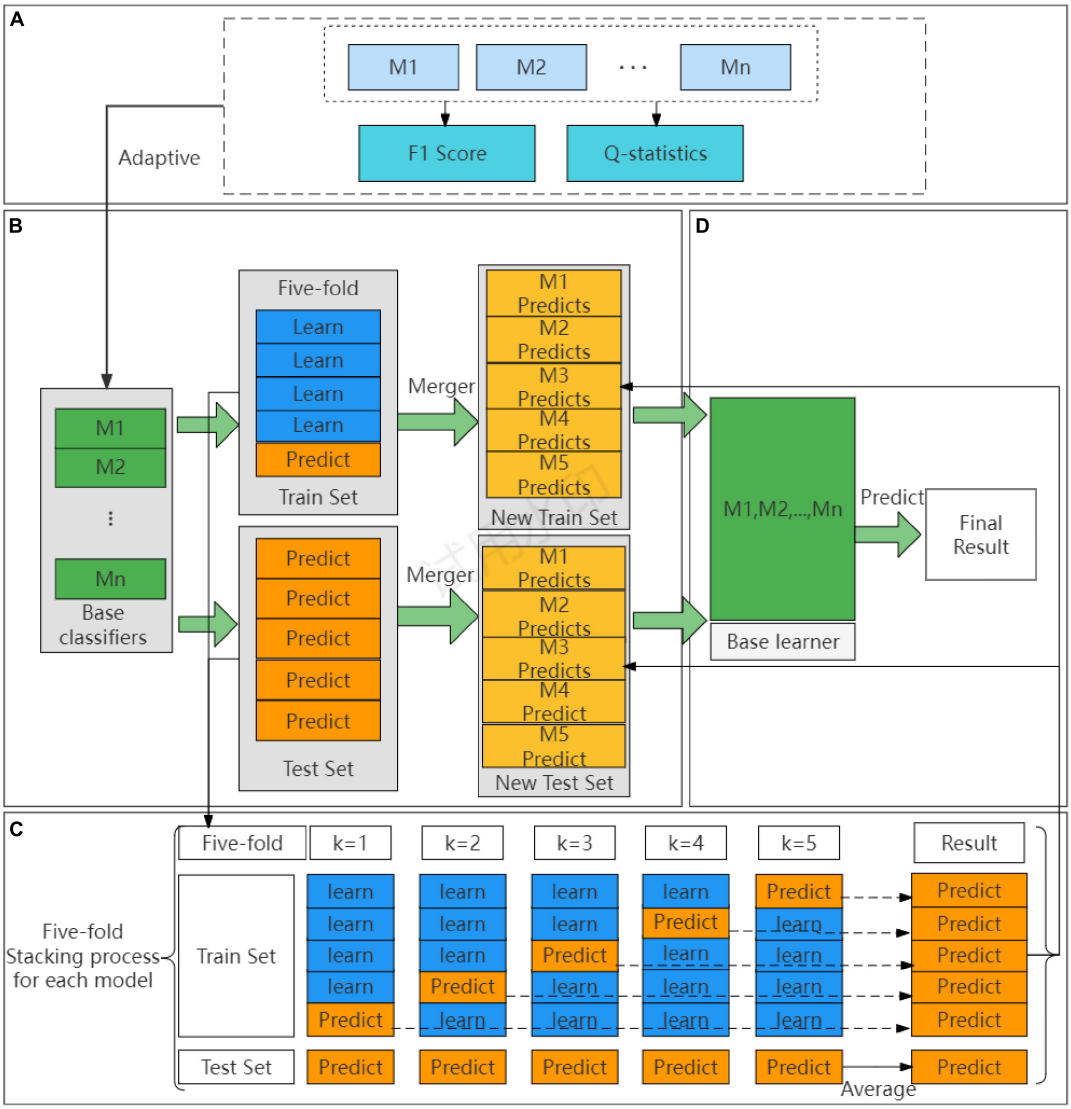


FIGURE 2
The process of adaptive Stacking model. **(A)** Adaptive selection base classifier process. **(B)** Process of building a base classifier. **(C)** Cross-validation detailed process. **(D)** Building a meta-learner process.

TABLE 2 Relationship between two pre-selected model.

	M_k correct (1)	M_k wrong (0)
M_i correct (1)	N_{11}	N_{10}
M_i wrong (0)	N_{01}	N_{00}

diabetic and non-diabetic interviews, totaling 70,691 samples. This dataset contains 21 characteristic variables as shown in Table 1.

2.2 Feature selection

Feature selection is an important technique in machine learning to filter out the most valuable and relevant sample features in the data for use in building machine learning models (27, 28). The purpose of feature selection is to reduce the number of sample features in the data, improve the accuracy and operational efficiency of the model, reduce the risk of overfitting, and improve the interpretability of the model (29). Not all sample features have a significant impact on the prediction results, which contains many sample features with low or irrelevant contribution to the prediction results, and too many sample features will cause computational resource consumption and reduce the training speed of the model, and may also reduce the accuracy of the model, so this chapter is to eliminate the sample features with low or irrelevant contribution to the prediction results. There are three common feature selection methods: filter, wrapper, and embedding (30). Since embedding methods have better predictive performance than filter methods and run much faster than wrapper methods (31), our study uses the embedding method GBDT to select feature variables.

GBDT is an ensemble learning method that improves the predictive performance of a model by constructing a series of weak learners (usually decision trees). The basic idea of GBDT is to

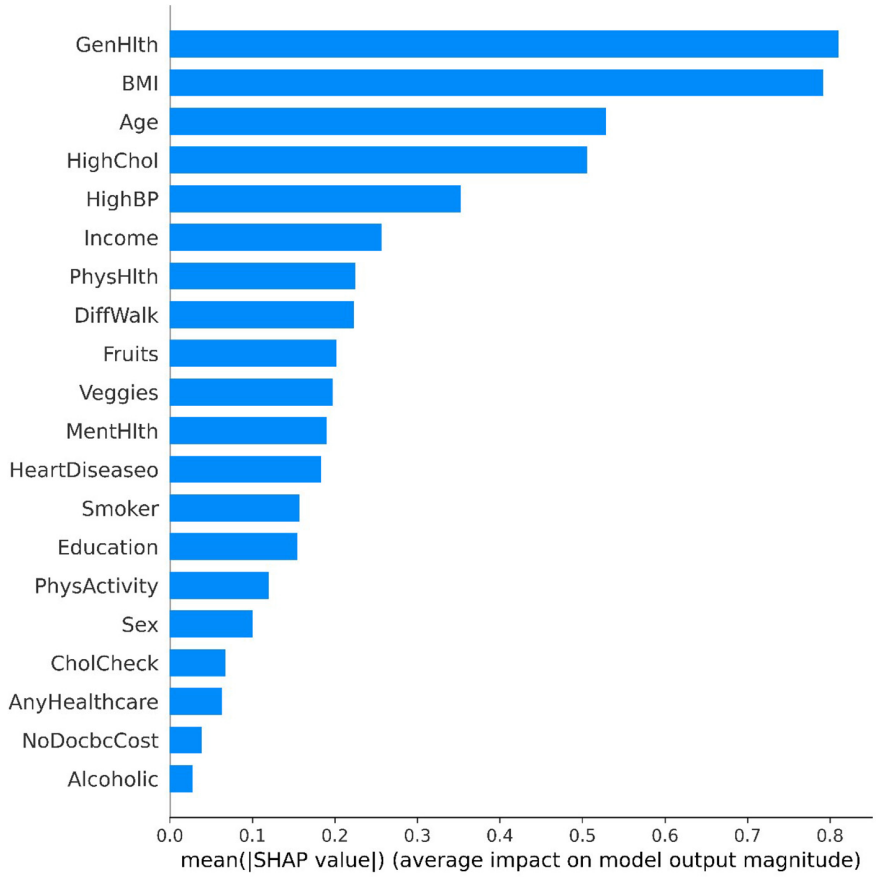


FIGURE 3
Global feature contributions.

combine multiple simple models (weak learners) so that each new model corrects as much as possible the errors of the previous model. Since the decision tree splits based on the importance of the features and features with high importance are more frequently selected as split points, GBDT can rank the importance of the features and handle high dimensional data. Secondly, GBDT can handle different types of features, including numerical and categorical. Finally, GBDT focuses on the residuals of the current model rather than modeling the target values directly, which makes the model more tolerant to noisy data.

When we use GBDT with embedding method to obtain feature importance ranking, one of the problems we face is the inability to accurately interpret the impact of individual features on the final prediction results. To solve this problem, we used a technique called feature interpolation method (32). This method represents the explanatory model as a linear function of the feature interpolation values, thus providing a clearer understanding of the model behavior. By this method we can reduce the repetition rate and better understand the contribution of individual features to the prediction results. The method is formulated as follows.

$$l\left(z^{'} = \emptyset_0 + \sum_{i=1}^{N} \emptyset_i Z_i^{'}\right) \quad (1)$$

Where N is the number of features, $\emptyset_i$ is the value of the feature attribute of the feature, $Z_i^{'} = 0$ or 1 to indicate whether the feature is observed or not, where the feature attribute can be regarded as the "feature contribution."

In order to compute the $\emptyset_i$ values in Equation 1, a tree-value estimation method based on game theoretic ideas (33), the SHAP method, is introduced as feature attribute values. In this method, the model f and the set S contain non-zero indexes in $z^{'}$ and each feature has the classical Shapley value attribute $\emptyset_i$, which is formulated in Equation 2.

$$\emptyset_i = \sum_{S \in M\{i\}} \frac{|S|!\,(N - |S| - 1)!}{N!} \left[f(S \cup \{i\} - f(S))\right] \quad (2)$$

where M is the set of all input features.

The SHAP method is a locally accurate, personalized feature attribution method that, unlike tree model gain, provides consistent global feature attribute results (34). In our study, we use the SHAP method for feature filtering and interpretation of individual feature attributes, which helps to reduce the repetition rate and provide a clearer understanding of the impact of each feature on the results.

2.3 Model building

When the base classifiers predict accurately, the greater the variability of the base classifiers, the better the integration of the model will be, which is the famous "error- ambiguity

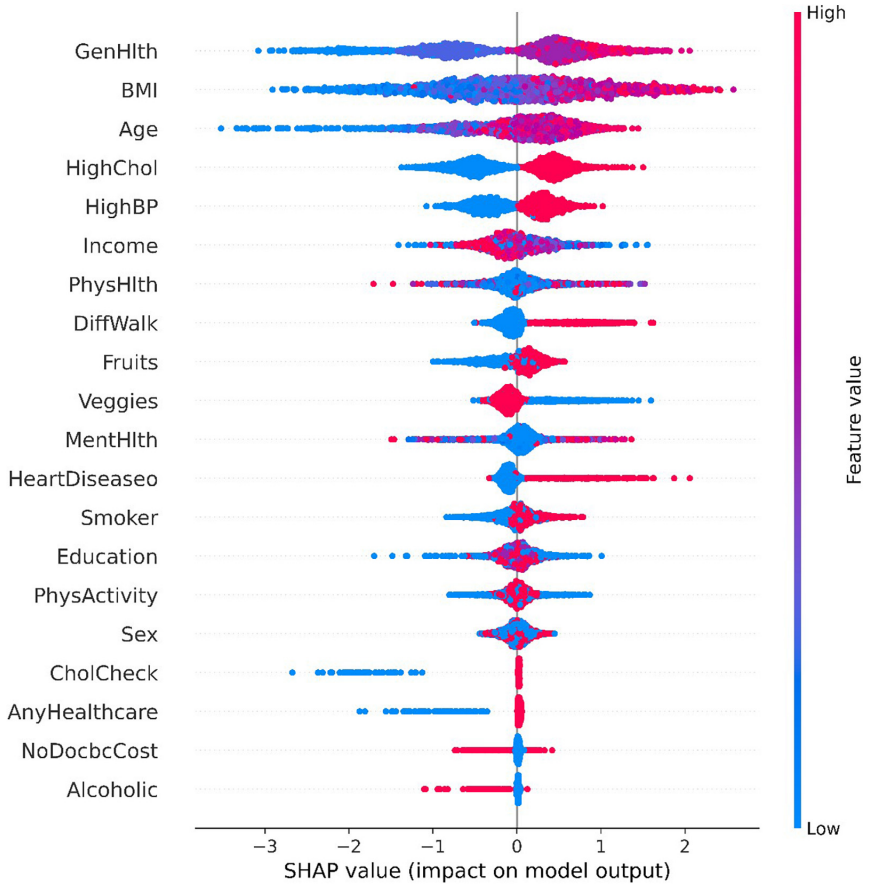


FIGURE 4
Comparision of individual feature contributions.

decomposition" theory. This implies that the variability of the base classifiers should be taken into account while guaranteeing the prediction effect of the base classifiers.

In principle, as long as the base classifier of the Stacking ensemble model predicts well (35), the number of layers of the Stacking ensemble model can be stacked infinitely, but this increases the complexity of the model. Therefore, we try to reduce the model complexity as much as possible while ensuring the prediction effect of the model, and only select the Stacking ensemble model, with the two-layer structure of the base layer and the convergence layer. To solve the problem of randomness of the traditional Stacking ensemble model, in selecting base classifiers and meta-learners, this paper proposes an adaptive Stacking ensemble model, and the process is shown in Figure 2.

The first step is to adaptively construct the base classifier of the Stacking base layer, as shown in Figure 2A. When choosing the base classifiers, the traditional Stacking ensemble model usually select the classifiers with good prediction effect, ignoring the principle of "error- ambiguity decomposition." In this paper, we design a method to adaptively construct the base classifiers of Stacking, from the pre-selected models of $M1$,$M2$, ...,Mn, according to the F1 value of the comprehensive evaluation metrics, we set a threshold to adaptively select the pre-selected models from the high to the low to construct the base classifiers, which is a step to ensure the prediction effect of the models. To ensure the variability of the models, this paper chooses the Q-statistics method (36) to compare the variability between the pre-selected models.

The detailed steps of the Q-statistics method are as follows, labeling the DM dataset as $Z = z_1, z_2, \ldots, z_n$, the pre-selected model as M_i, after using n pre-selected models for classification prediction, if the pre-selected model M_i predicts the ensemble correctly it will be 1, and the prediction is wrong it will be 0, and the relationship between the two pre-selected models is shown in Table 2.

The differential Q-statistics for the two pre-selected model M_i, M_k are shown in Equation 3 as follows.

$$Q_{i,k} = \frac{N_{11}N_{00} - N_{01}N_{10}}{N_{11}N_{00} + N_{01}N_{10}} \tag{3}$$

Statistically, the expected value of two completely independent pre-selection models $Q_{i,k}$ is 0. The range of Q is between [−1, 1], and the smaller the absolute value, the greater the variability between the pre-selection models. In the L pre-selection models of this paper, the average value of Q is shown in Equation 4.

$$Q_{avg} = \frac{2}{L(L-1)} \sum_{L-1}^{i=1} \sum_{L}^{k=i+1} Q_{i,k} \tag{4}$$

The steps for adaptively constructing a base classifier for the Stacking ensemble model, are shown below:

Algorithm 1 Adaptive Stacking algorithm.

Symbols are defined: threshold λ, F_i^N is the F1 value of M_i, ⊙ is the model satisfying the discreteness condition, M is the set of base classifiers, the train set T and the test set S, T_{ft} is the training set for the five-fold cross-validation, S_{fv} is the test set for the five-fold cross validation, εl is the base classifier, LR_{meta} is the meta learners, T^l is the train set for εl, and S^l is the test set for εl

1. **For** N = [M_1, M_2,...,M_n] // Preselection model
2. **If** $F_i^N > \lambda$ // Determine if the F1 value of model M_i is greater than a threshold value
3. **If** $M = \emptyset$ // Determine if M is empty
4. $M = M + M_i$ // Model M_i is added to M
5. **If** $M_i \odot Mj$ // Determine whether two models satisfy the difference condition
6. $M = M + Mj$ // Model M_j is added to M
7. **For** l = M = [M_1, M_2, ..., M_n] // Base classifiers
8. **For** k = 1,2, ...,5
9. $T_{ft}^l \rightarrow \odot l$ // Use T_{ft}^l to train εl
10. $S_{fv}^l \rightarrow \varepsilon l \rightarrow train_f, S^l \rightarrow \varepsilon l \rightarrow test_f$ // Predict S_{fv}^l,S^l by εl to get $train_f$,$test_f$
11. $train_l = (train_1 + train_2 + ... + train_5)$ // Vertical stack
12. $test_l = (test_1 + test_2 + ...+ test_5)/5$ // Level average
13. $train_{new}$ = [$train_1$,$train_2$,... $train_5$] and $train_{new}$ = [$train_1$,$train_2$,... $train_5$]
14. $train_{new} \rightarrow LR_{meta}$ //Train LR_{meta} with $train_{new}$
15. $test_{new} \rightarrow LR_{meta} \rightarrow result_{pre}$ //Predict $test_{new}$. with LR_{meta} to get the final result
16. **Return** $result_{pre}$ // Returns the final prediction

(1) Train n pre-selected models M_1,M_2, , M_n.
(2) Calculate the comprehensive evaluation metrics F1 value of the n pre-selected models, and set the threshold as the average F1 value.
(3) Eliminate the models with F1 values smaller than the threshold and retain the models with F1 values larger than the threshold.
(4) Models with small variance are eliminated and models with large variance are retained based on Q-statistics.
(5) Select M_1,M_2,,M_n as the final base classification.

Figure 2B shows the cross-validation part of the adaptive Stacking ensemble model. After adaptive selection as base classifiers, the train set and test set are divided according to an 8:2 ratio. In the train set, each base classifier using five-fold cross-validation. Taking five base classifiers $M1$,$M2$,, M_5 as an example, the specific operation is shown in Figure 2D. A base classifier can get five predictions, which are vertically stacked into a one-dimensional matrix. Five base classifiers can be combined into a five-dimensional matrix as a new train set for the convergence layer. In the test set, again each base classifier using five-fold cross-validation and again five predictions are obtained. To ensure the division ratio between the train set and test set, the predictions of the test set are horizontally averaged to obtain a one-dimensional matrix. The predictions of the five base classifiers are combined into a five-dimensional matrix that serves as a new test set for the convergence layer.

The second step adaptively constructs the meta-learner of the Stacking ensemble model. As shown in Figure 2C, this paper traverses the whole base classifier model to select the meta-learner, and obtains the final prediction result through the meta-learner.

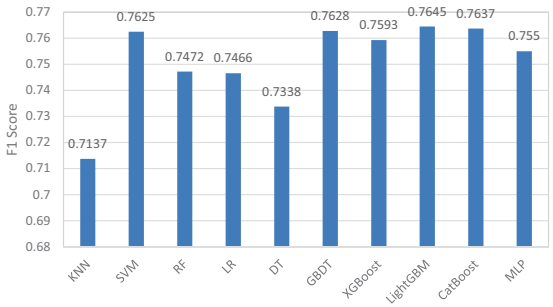


FIGURE 5
F1 values for 10 pre-selected models.

Finally, to better understand the implementation process of the Adaptive Stacking algorithm, this paper gives the pseudo-code of the Adaptive Stacking algorithm, as shown in Algorithm 1.

Typically, machine learning evaluates the performance of a model using True Positive (TP), True Negative (TN), False Positive (FP) and False Negative (FN) metrics. The commonly used accuracy, precision, recall and F1 score are calculated from these metrics, which can be calculated by referring to Equations 5–8.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{5}$$

$$Precision = \frac{TP}{TP + FP} \tag{6}$$

$$Recall = \frac{TP}{TP + FN} \tag{7}$$

$$F1 = 2 \times \frac{Precision \times Recall}{Precision \times Recall} \tag{8}$$

3 Results and discussion

3.1 Results of feature selection and analysis

The tree SHAP method calculates the individual contribution value of each feature in the sample dataset. Figure 3 demonstrates the global feature contribution in the GBDT model, the horizontal coordinate represents the sample feature contribution, the larger the value, the more important the sample feature is, and the vertical coordinate is the sample feature based on the feature importance from the largest to the smallest. From the figure, it can be seen that the features "GenHlth" and "BMI" have significant contribution degrees, which indicates a strong correlation with diabetes. While the inverse features "CHolCheck," "AnyHealthcare," "NoDocbcCost," and "Alcoholic" features have less than 0.1 contribution, this paper directly excludes these four features and finally retains 16 sample features.

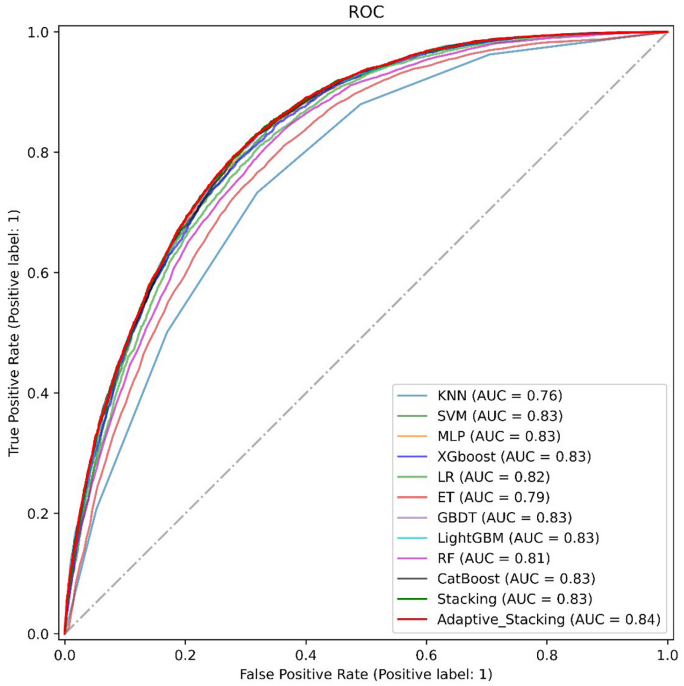


FIGURE 6
ROC curve on DM.

TABLE 3 Results of classifiers.

Model	Accuracy	Precision	Recall	F1 score
KNN	0.7068	0.6954	0.733	0.7137
SVM	0.74.9	0.7217	0.8081	0.7625
RF	0.7371	0.7176	0.7794	0.7472
LR	0.741	0.7289	0.7652	0.7466
DT	0.7232	0.7048	0.7652	0.7338
GBDT	0.7536	0.73.3	0.7949	0.7628
XGBoost	0.7493	0.7283	0.7932	0.7593
LightGBM	0.7547	0.7331	0.7987	0.7645
CatBoost	0.7557	0.7336	0.8008	0.7637
MLP	0.7493	0.7362	0.7746	0.755
Stacking	0.7554	0.7307	0.8007	0.7668
Adaptive Stacking	**0.7559**	0.7286	**0.8132**	**0.7686**

The results with the best predictions are highlighted in bold.

The Tree SHAP values depend on how the features are interpreted, so we can obtain the feature interpretation for each sample from the model (37). Figure 4 presents some information about the contribution of individual features to the model output and details how their values affect the model. the *x*-axis indicates the magnitude of the feature contribution, while the magnitude of the feature value is indicated by the color of the different points. The highest contribution of characteristics, "GenHlth" indicates that the poorer the physical condition the more likely to get diabetes, and similarly from the second and third ranked "BMI" and "Age," it can be seen that the higher the weight coefficient the more likely to get diabetes, and the higher the age the more likely to get diabetes.

3.2 Results of the proposed adaptive Stacking ensemble model

In the adaptive Stacking ensemble model, the 10 pre-selected models are sorted according to the size of the F1 value, and the sorting results are shown in Figure 5. The horizontal coordinates in the figure indicate the 10 pre-selected models and the vertical coordinates indicate the F1 values of the pre-selected models.

In this paper, we set the average of F1 values as the threshold and first excluded four pre-selected models, K-nearest neighbor (KNN), RF, logistic regression (LR) and decision tree (DT). Four models, support vector machine (SVM), multilayer perceptron (MLP) and XGBoost and CatBoost, are selected as base classifiers from the remaining six pre-selected models adaptively based on Q-statistics. The top-ranked GBDT model and LightGBM model have better prediction results, but the difference between them and CatBoost model is proved to be small by Q-statistics method, so these two models are eliminated in adaptive way. In the selection of meta-learner, this paper traverses all the base classifier models and selects the optimal meta-learner according to the evaluation metrics.

In this paper, the prediction results of 10 pre-selected models, traditional Stacking ensemble model, and the adaptive Stacking ensemble model proposed in this paper are compared by four evaluation metrics: Accuracy, Precision, Recall and F1 value, and the comparison results are shown in Table 3. It can be seen that compared with the traditional machine learning models KNN and SVM, the traditional Stacking ensemble model outperforms the single classification model in predicting DM. The adaptive Stacking ensemble model proposed in this paper has very high accuracy, recall and F1 values of 0.7559, 0.8132 and 0.7668, which are

higher than the traditional Stacking ensemble model. The adaptive Stacking ensemble model proposed in this paper is completely better than the traditional Stacking ensemble model, and can adaptively make the best adjustment. This shows that the adaptive Stacking ensemble model has obvious advantages in predicting DM.

Finally, this paper plots the ROC curves of 11 representative models with the adaptive Stacking ensemble model, as shown in Figure 6. In the dataset of this paper, the ensemble learning model predicts better than traditional machine learning, and the AUC value of the ensemble learning model reaches 0.83. Among the Stacking ensemble model is better than the Bagging model and the Boosting model. The AUC value of the adaptive Stacking ensemble model reaches 0.84, which is higher than the traditional Stacking ensemble model. This shows that the adaptive superposition ensemble model proposed in this paper has excellent prediction effect in predicting DM.

4 Conclusion

In this paper, we propose a DM prediction model based on adaptive Stacking and analyze it in comparison with 10 pre-selected models and traditional Stacking ensemble model by five evaluation metrics: accuracy, precision, recall, F1 value and AUC value. The results show that the adaptive Stacking ensemble model proposed in this paper outperforms other models in several evaluation metrics, with accuracy, precision, recall, F1 value, and AUC value of 0.7559, 0.7268, 0.8132, 0.7686, and 0.8436, which suggests that the adaptive Stacking ensemble model, proposed in this paper is able to integrate the advantages of a single model and adaptive selection of pre-selected models to obtain better prediction results, which can provide clinical diagnostic advice and decision support for doctors and provide patients with appropriate medical and health management as early as possible. Although the adaptive Stacking model proposed in this study has a better prediction effect compared to a single model, the model complexity is high, and the complexity of the model needs to be further optimized according to the actual application scenarios. In addition, this study is limited to the study of machine learning models, and will collect more datasets and try to use deep learning models for the study. Finally, we stay on top of recently released healthcare policies, continually communicating with local hospitals and healthcare professionals to collect data on patient metrics.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: https://www.kaggle.com/datasets/alexteboul/diabetes-health-indicators-dataset.

Author contributions

QD: Data curation, Software, Writing – original draft, Writing – review & editing. DW: Data curation, Supervision, Formal analysis, Project administration, Writing – review & editing. YZ: Writing – original draft, Writing – review & editing.

Funding

The authors declare that financial support was received for the research, authorship, and/or publication of this article. This study was supported by the National Natural Science Foundation of China (No. 81173183), the Natural Science Foundation of Shandong Province (No. ZR2020KH003), the Shandong Province Higher Educational Institutions' Youth Creative Talent Inducement Programmer Project (Year.2021), and the Open Project of the Key Laboratory of Classical Theory of Traditional Chinese Medicine of the Ministry of Education.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Choudhury AA, Rajeswari VD. Gestational diabetes mellitus-A metabolic and reproductive disorder. *Biomed Pharmacother.* (2021) 143:112183.

2. Onuigwe F, Ambi H, Uchechukwu N, Obeagu E. Platelet dysfunction in diabetes mellitus. *Elite J Med.* (2024) 2:1–7.

3. Vlacho B, Rossell-Rusiñol J, Granado-Casas M, Mauricio D, Julve J. *Overview on chronic complications of diabetes mellitus. Chronic complications of diabetes mellitus.* Amsterdam: Elsevier (2024).

4. Alam MM. *Prevalence of type 2 diabetes mellitus complications in human.* Chittagong: Chattogram Veterinary & Animal| Sciences University (2021).

5. Ikwuka AO, Omoju DI, Mahanera OK. Profiling of clinical dynamics of type 2 diabetes mellitus in patients: A perspective review. *World J Curr Med Pharm Res.* (2023) 5:210–8.

6. Picca A, Ronconi D, Coelho-Junior HJ, Calvani R, Marini F, Biancolillo A, et al. The "development of metabolic and functional markers of dementia in older people" (Odino) study: Rationale, design and methods. *J Pers Med.* (2020) 10:22.

7. Alanazi HO, Abdullah AH, Qureshi KN. A critical review for developing accurate and dynamic predictive models using machine learning methods in medicine and health care. *J Med Syst.* (2017) 41:1–10.

8. Kopitar L, Kocbek P, Cilar L, Sheikh A, Stiglic G. Early detection of type 2 diabetes mellitus using machine learning-based prediction models. *Sci Rep.* (2020) 10:11981.

9. Ganie SM, Malik MB. Comparative analysis of various supervised machine learning algorithms for the early prediction of type-Ii diabetes mellitus. *Int J Med Eng Inform.* (2022) 14:473–83.

10. Laila UE, Mahboob K, Khan AW, Khan F, Taekeun W. An ensemble approach to predict early-stage diabetes risk using machine learning: An empirical study. *Sensors.* (2022) 22:5247.

11. Muhammad L, Algehyne EA, Usman SS. Predictive supervised machine learning models for diabetes mellitus. *SN Comput Sci.* (2020) 1:240.

12. Malik S, Harous S, El-Sayed H. Comparative analysis of machine learning algorithms for early prediction of diabetes mellitus in women. *Proceedings of the international symposium on modelling and implementation of complex systems*. Cham: Springer (2020). p. 95–106.

13. Rodríguez-Rodríguez I, Rodríguez J-V, Woo WL, Wei B, Pardo-Quiles D-J. A comparison of feature selection and forecasting machine learning algorithms for predicting glycaemia in type 1 diabetes mellitus. *Appl Sci.* (2021) 11: 1742.

14. Ali, MS, Islam MK, Das AA, Duranta D, Haque M, Rahman MH. A novel approach for best parameters selection and feature engineering to analyze and detect diabetes: Machine learning insights. *BioMed Res Int.* (2023) 2023.

15. Tasin I, Nabil TU, Islam S, Khan R. Diabetes prediction using machine learning and explainable AI techniques. *Healthc Technol Lett.* (2023) 10:1–10.

16. Chou C-Y, Hsu D-Y, Chou C-H. Predicting the onset of diabetes with machine learning methods. *J Pers Med.* (2023) 13:406.

17. Abegaz TM, Ahmed M, Sherbeny F, Diaby V, Chi H, Ali A. Application of machine learning algorithms to predict uncontrolled diabetes using the all of us research program data. *Healthcare.* (2023) 11:1138.

18. Su Y, Huang C, Yin W, Lyu X, Ma L, Tao Z. Diabetes Mellitus risk prediction using age adaptation models. *Biomed Signal Process Control.* (2023) 80:104381.

19. Zohair M, Chandra R, Tiwari S, Agarwal S. A model fusion approach for severity prediction of diabetes with respect to binary and multiclass classification. *Int J Inform Technol.* (2024) 16:1955–65.

20. Doğru A, Buyrukoğlu S, Arı M. A hybrid super ensemble learning model for the early-stage prediction of diabetes risk. *Med Biol Eng Comput.* (2023) 61:785–97.

21. Mienye ID, Sun Y. Improved heart disease prediction using particle swarm optimization based stacked sparse autoencoder. *Electronics.* (2021) 10: 2347.

22. Cui S, Yin Y, Wang D, Li Z, Wang Y. A stacking-based ensemble learning method for earthquake casualty prediction. *Appl Soft Comput.* (2021) 101:107038.

23. Liang M, Chang T, An B, Duan X, Du L, Wang X, et al. A stacking ensemble learning framework for genomic prediction. *Front Genet.* (2021) 12:600040. doi: 10.3389/fgene.2021.600040

24. Liu J, Dong X, Zhao H, Tian Y. Predictive classifier for cardiovascular disease based on stacking model fusion. *Processes.* (2022) 10:749.

25. Zhou Z-H, Wu J, Tang W. Ensembling neural networks: Many could be better than all. *Artif Intell.* (2002) 137:239–63.

26. Liang W, Luo S, Zhao G, Wu H. Predicting hard rock pillar stability using GBDT, XGBoost, and LightGBM algorithms. *Mathematics.* (2020) 8:765.

27. Khalid S, Khalil T, Nasreen S. A survey of feature selection and feature extraction techniques in machine learning. *Proceedings of the 2014 science and information conference*. New York, NY: IEEE (2014). p. 372–8.

28. Solorio-Fernández S, Carrasco-Ochoa JA, Martínez-Trinidad JF. A review of unsupervised feature selection methods. *Artif Intell Rev.* (2020) 53:907–48.

29. Dougherty ER. Feature-selection overfitting with small-sample classifier design. *Proceedings of the IEEE computer society 10662 LOS VAQUEROS CIRCLE, PO BOX 3014*. Los Alamitos, CA: (2005).

30. Yang P, Huang H, Liu C. Feature selection revisited in the single-cell era. *Genome Biol.* (2021) 22:1–17.

31. Senliol B, Gulgezen G, Yu L, Cataltepe Z. Fast correlation based filter (FCBF) with a different search strategy. *Proceedings of the 2008 23rd international symposium on computer and information sciences*. Berlin: IEEE (2008). p. 1–4.

32. Parsa AB, Movahedi A, Taghipour H, Derrible S, Mohammadian AK. Toward safer highways, application of XGBoost and Shap for real-time accident detection and feature analysis. *Accident Anal Prev.* (2020) 136:105405.

33. Lundberg SM, Erion GG, Lee S-I. Consistent individualized feature attribution for tree ensembles. *arXiv* [Preprint]. (2018). arXiv:1802.03888.

34. Holzinger A, Saranti A, Molnar C, Biecek P, Samek W. Explainable AI methods-a brief overview. *Proceedings of the international workshop on extending explainable AI beyond deep models and classifiers*. Springer (2022). p. 13–38.

35. Soleymanzadeh R, Aljasim M, Qadeer MW, Kashef R. Cyberattack and fraud detection using ensemble stacking. *AI.* (2022) 3:22–36.

36. Barbosa JC, Willoughby P, Rosenberg CA, Mrtek RG. Statistical methodology: VII. Q-methodology, a structural analytic approach to medical subjectivity. *Acad Emerg Med.* (1998) 5:1032–40.

37. Lundberg SM, Lee S-I. A unified approach to interpreting model predictions. *Adv Neural Inform Process Syst.* (2017) 30:4768–77.

frontiers | Frontiers in Medicine

TYPE Original Research
PUBLISHED 03 October 2024
DOI 10.3389/fmed.2024.1324939

OPEN ACCESS

EDITED BY
Muhammad Azeem Ashraf,
Hunan University, China

REVIEWED BY
Eiji Kawamoto,
Mie University, Japan
Greta Mazzetti,
University of Bologna, Italy

*CORRESPONDENCE
Zhiyong Liu
✉ zhiyongliu@hust.edu.cn

RECEIVED 29 November 2023
ACCEPTED 30 August 2024
PUBLISHED 03 October 2024

CITATION
Wang X, Hou S, Lv Q, Liu Y, Wu H and Liu Z (2024) The association of social networks with the job performance of primary health care professionals: the mediating effect of knowledge sharing. *Front. Med.* 11:1324939. doi: 10.3389/fmed.2024.1324939

The association of social networks with the job performance of primary health care professionals: the mediating effect of knowledge sharing

Xiubo Wang[1], Shengchao Hou[1,2], Qiongxin Lv[3], Yuxin Liu[1], Huan Wu[1,4] and Zhiyong Liu[1]*

[1]School of Medicine and Health Management, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China, [2]Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China, [3]Shenzhen Children's Hospital, Shenzhen, China, [4]School of Management, Xinxiang Medical University, Xinxiang, China

Background and aims: Social networks formed through social media platforms have facilitated knowledge sharing among primary health care professionals (PHCPs). However, the impact of these networks on PHCPs' job performance and the mediating role of knowledge sharing remain underexplored. This study aimed to investigate the association between social networks formed via social media and the job performance of PHCPs, and to explore the mediating role of knowledge sharing in this association.

Methods: A cross-sectional survey was carried out among PHCPs in Henan Province, China, involving 655 valid responses. Validated scales measured the key variables, and structural equation modeling (SEM) tested the proposed hypotheses, including the mediating effect of knowledge sharing through bootstrap method. Statistical analysis was performed using SPSS 24.0 and AMOS 24.0.

Results: The degree centrality ($\beta = 0.225$; $p = 0.001$) and network heterogeneity ($\beta = 0.093$; $p = 0.043$) of the social network had a significant direct association with job performance, whereas the direct associations of betweenness centrality and network tie strength with job performance were not significant. Knowledge sharing mediated the relationship between degree centrality ($\beta = 0.147$; $p = 0.001$), network heterogeneity ($\beta = 0.251$; $p = 0.043$), and job performance.

Conclusion: The study revealed the internal mechanisms by which social network characteristics influence PHCPs' job performance, highlighting the mediating role of knowledge sharing. Social networks formed within social media contexts have multifaceted effects on job performance, with knowledge sharing as a critical mediating variable. These findings underscore the importance of leveraging social media for professional networking and knowledge exchange to enhance PHCPs' job performance.

KEYWORDS

social networks, knowledge sharing, job performance, social media, primary health care professional

1 Introduction

Primary health care (PHC) entails the provision of integrated and accessible essential healthcare services by healthcare professionals, with a primary focus on addressing the basic health needs of individuals and communities. PHC stands as a key model for promoting public health globally. Notably, in China, the government has accorded high priority to the development of PHC. Since the initiation of comprehensive healthcare reforms in 2009, China has implemented a series of pivotal policies, including the establishment of the national hierarchical medical system, the introduction of medical consortia, and the reinforcement of PHC institutions. These measures were designed to enhance residents' accessibility to PHC and optimize resource allocation within PHC institutions (1, 2). Despite these comprehensive reforms leading to remarkable improvements in PHC service capacity (3), a persistent gap persists between the intended policy objectives and the actual state of development. This gap primarily arises from the incapacity of primary healthcare professionals (PHCPs) to meet the escalating demand for PHC services among residents (4).

PHCPs occupy a pivotal role as frontline professionals actively engaged in the delivery of PHC services, effectively functioning as the "gatekeepers" of residents' health. Their performance exerts a decisive influence on the substantial enhancement of PHC service capacity and the successful execution of healthcare reforms. The concept of PHCPs' job performance encompasses a composite of behaviors, skills, and abilities demonstrated by these professionals in the execution of their duties and responsibilities to achieve organizational objectives within the healthcare sector (5). This construct is influenced by several factors, such as financial incentives, workload, social support, leadership, job satisfaction, and knowledge sharing (6–11). Knowledge sharing, in this context, is defined as the process through which healthcare professionals exchange, disseminate, and co-create knowledge and information within their networks. This includes transferring skills, experiences, and insights through interactions facilitated by social media platforms, which operate on both explicit and tacit levels.

Despite these insights, the impact of organizational attributes on PHCPs' job performance has often overlooked the critical role played by social networks, which are formed through interactions among employees within organizations. These social networks, integral components of the organizational fabric, have substantial influence over both individual and collective performance (12).

The exploration of social networks and job performance has become inextricably intertwined with the realm of social media in recent times. Social media, defined as a collection of online applications and platforms built upon the ideological and technological foundations of Web 2.0, is intrinsically linked to specific networks of user social connections, enabling users to create, share, and seek content (13–15). In China, widely utilized social media platforms, such as WeChat, Tencent QQ, and DingTalk, play a pivotal role in fostering interpersonal networks (16, 17). A 'social network' in this context refers to the structure of relationships and interactions among individuals, specifically health care professionals, which are facilitated by digital platforms. These networks are characterized by nodes (individual actors, people, or things within the network) and ties (the relationships or interactions between these actors). Functionally, social networks facilitate the sharing of information, collaboration, and peer support among professionals, thereby enhancing communication and coordination within healthcare settings.

Before COVID-19, social media adoption in healthcare was steadily growing due to its potential for enhancing communication and collaboration. The pandemic has accelerated this trend, making social media vital for maintaining professional networks and exchanging critical medical information. With face-to-face interactions limited, social media has become essential for sustaining social networks among PHCPs, facilitating efficient knowledge exchange. This increased reliance highlights the need to explore how these networks impact PHCPs' job performance, especially in a rapidly evolving digital healthcare environment (18, 19). However, research addressing the impact of social networks on PHCPs' job performance within the context of social media environments remains limited, with the underlying mechanisms of this relationship still unclear.

In consideration of these factors, this study endeavors to investigate how the structural and relational characteristics of PHCPs' social networks via social media influence their job performance. Furthermore, the study will delve into the role of knowledge sharing as an intermediary variable within this relationship, illuminating the intricate mechanisms that underscore the effect of social network characteristics on job performance within the context of social media. The results of this study can provide a reference for PHC institutions to create an organizational environment conducive to better interpersonal synergies and high-quality healthcare service.

2 Research model and hypothesis development

2.1 Social networks and job performance

The social network is a collection of relationships including kinship, friendship, and superior-subordinate relationships in an organization (20, 21). Social media is a popular tool utilized by health care professionals to meet their professional needs, creating a social network that is more accessible than engaging in face-to-face interactions (22). As indicated by Burt and Granovetter's study, social networks can be conceptualized in terms of two dimensions: structure and relationships (23, 24). In this study, the structural dimension considers network centrality and heterogeneity, while the relational dimension is assessed through network tie strength.

Network centrality is used to represent the overall structure of social networks and can be measured by degree centrality and betweenness centrality (25–27). In the context of healthcare, degree centrality refers to the number of direct connections that a healthcare worker has with other workers within the healthcare system. Betweenness centrality measures the extent to which a healthcare worker lies on the shortest path between other pairs of workers within the healthcare system. According to social capital theory, a higher degree centrality and betweenness centrality leads to greater access to social benefits in the network, facilitating problem solving and relationship building at work and thereby improving individual performance (28). Previous studies have demonstrated positive relationships between the network centrality of personal networks and individual performance (29–32). PHCPs with high degree centrality

usually have enhanced connectivity and access to valuable resources and information. PHCPs with high betweenness centrality act as intermediaries and can facilitate communication and collaboration among different parts of the healthcare system, which can lead to more effective teamwork and better patient outcomes.

Network heterogeneity refers to the number and types of differences that exist between PHCPs in a given social network (33, 34). The use of social media tools enables healthcare professionals to more easily establish connections and expand their network heterogeneity. This can positively influence their job performance, as they are more likely to receive support from individuals with diverse perspectives, experiences, and knowledge backgrounds, thus fostering their confidence in delivering high-quality patient care.

Network tie strength refers to the frequency of contact and emotional closeness between PHCPs in a social network (24, 35, 36). It is noteworthy that in Chinese guanxi society, strong ties play a more important role than weak ties in facilitating collaboration and information exchange among individuals (37). Connections via social media between PHCPs and their colleagues can make the transmission of information faster and more extensive, leading to enhanced job satisfaction and increased work efficiency and ultimately resulting in better performance.

Based on the above analysis, we hypothesize as follows:

> *H1:* Social networks of PHCPs have a significant positive effect on job performance.
>
> *H1a:* The degree centrality of PHCPs has a significant positive effect on job performance.
>
> *H1b:* The betweenness centrality of PHCPs has a significant positive effect on job performance.
>
> *H1c:* The network heterogeneity of PHCPs has a significant positive effect on job performance.
>
> *H1d:* The network tie strength of PHCPs has a significant positive effect on job performance.

2.2 Social networks and knowledge sharing

Knowledge sharing represents a dynamic process through which knowledge is transmitted from the knowledge owner to the recipient, subsequently assimilated, and internalized by the latter (38, 39). It is noteworthy that social networks can serve as potent motivators for knowledge sharing endeavors (40). The advent of social media platforms has greatly facilitated the practice of knowledge sharing (41). Individuals' proclivity for knowledge sharing is significantly influenced by their roles and positions within their respective social networks. Specifically, PHCPs occupying pivotal positions characterized by high degree and betweenness centrality are more inclined to partake in knowledge sharing activities within the confines of their social networks. PHCPs with a high degree centrality, owing to their extensive network connections, play a particularly advantageous role in sharing medical knowledge and responding to requests for assistance from colleagues. On the other hand, PHCPs with high betweenness centrality, a key attribute for efficiently diffusing and regulating information across diverse teams, are motivated by the desire to maintain their network leadership status, leading them to actively participate in the dissemination of knowledge (42).

Network heterogeneity serves as a catalyst for promoting knowledge sharing among PHCPs by facilitating diverse knowledge exploration (43). Social media platforms act as converging arenas for healthcare practitioners, encompassing a diverse array of backgrounds and geographical origins, each contributing unique expertise and experiential insights (14, 44). This convergence offers PHCPs convenient access to a multitude of novel ideas and information from disparate sources, thereby stimulating their proclivity for knowledge sharing. The intrinsic diversity within these networks possesses the inherent capability (45) to augment individual cognitive resources. In contrast to interactions with peers possessing similar knowledge and experiences, engagement with individuals characterized by contrasting knowledge and diverse experiences introduces PHCPs to a rich tapestry of innovative ideas and varying viewpoints. This, in turn, fosters a dynamic exchange of knowledge.

Network tie strength may have a positive impact on knowledge sharing. This phenomenon is particularly evident in the context of tacit knowledge exchange (46). Frequent social media interactions between PHCPs have been found to enhance the maintenance of close relationships while simultaneously promoting trust and collaboration (47). This, in turn, facilitates the dissemination of valuable information and enhances it, thereby augmenting the overall knowledge sharing process.

Thus, we hypothesize the following:

> *H2:* Social networks of PHCPs have a significant positive effect on knowledge sharing.
>
> *H2a:* The degree centrality of PHCPs has a significant positive effect on knowledge sharing.
>
> *H2b:* The betweenness centrality of PHCPs has a significant positive effect on knowledge sharing.
>
> *H2c:* The network heterogeneity of PHCPs has a significant positive effect on knowledge sharing.
>
> *H2d:* The network tie strength of PHCPs has a significant positive effect on knowledge sharing.

2.3 Social networks and job performance

Knowledge sharing is a crucial and valued social asset for organizations since it leads to improved job performance and enhances organizational success, particularly in social media environments (48, 49). Both explicit and tacit knowledge are shared to enhance individual and organizational performance by interrelating learning, practice, and peer input (50). Previous research has indicated that knowledge sharing promotes better job skills, greater job knowledge, and increased work efficiency, consequently leading to enhanced job performance (51–53). As a typical knowledge-intensive organization, PHCIs depend on knowledge sharing and learning innovation among PHCPs to enhance their core competitiveness and

improve the quality of healthcare services. Several studies have shown that sharing knowledge, including clinical knowledge, work skills, and experience, is conducive to the enhancement of clinical diagnosis and decision-making, as well as the optimization of healthcare services (54). Therefore, we hypothesize the following:

> *H3:* Knowledge sharing among PHCPs has a significant positive effect on job performance.

By synthesizing the analysis of both hypotheses 2 and 3, it is reasonable to further propose that knowledge sharing acts as a mediator between the social networks of PHCPs via social media and their job performance.

> *H4:* Knowledge sharing has a significant mediating effect between PHCPs' social networks and job performance.
>
> *H4a:* Knowledge sharing has a significant mediating effect between degree centrality and job performance.
>
> *H4b:* Knowledge sharing has a significant mediating effect between betweenness centrality and job performance.
>
> *H4c:* Knowledge sharing has a significant mediating effect between network heterogeneity and job performance.
>
> *H4d:* Knowledge sharing has a significant mediating effect between network tie strength and job performance.

Based on the analysis above, the hypothesized research model was developed and is presented in Figure 1. This research model investigates the relationships between social networks, knowledge sharing, and job performance among PHCPs. Specifically, it posits that degree centrality, betweenness centrality, network heterogeneity, and network tie strength directly influence job performance, with these effects being further mediated by knowledge sharing. By integrating social network theory and knowledge-sharing theory, this study aims to explore how the structural and relational characteristics of PHCPs' social networks within a social media environment impact their job performance. The model underscores the essential role of knowledge exchange as a mechanism for enhancing professional performance, thereby providing insights into the ways that effective collaboration and knowledge sharing can lead to improved outcomes in primary health care settings.

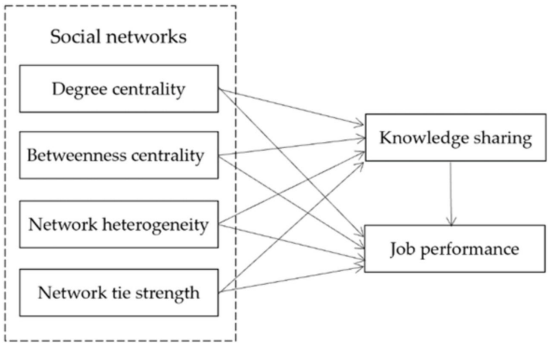


FIGURE 1
Research model.

3 Methodology

3.1 Measurement instrument

The questionnaire used in this study was obtained from a reliable source with proven validity and reliability. In this study, social networks are divided into four latent variables: degree centrality, betweenness centrality, network tie strength, and network heterogeneity. According to Freeman's (55) research, four measurement items for degree centrality and three for betweenness centrality were developed. Network heterogeneity is assessed using the five measurement items originally proposed by Marsden (56) and Harrison (57). Moreover, network tie strength is measured using three items adapted from the studies of Burt (23) and Granovetter (24). To measure knowledge sharing, this study references the scale developed by Bock (39, 58), comprising six items, specifically three for explicit knowledge sharing and three for tacit knowledge sharing. Additionally, the job performance scale was developed based on the previous research of Borman and Motowidlo (59, 60) and Van Scotter and Motowidlo (61), covering dimensions of task performance, interpersonal facilitation, and job dedication. Each dimension is assessed using three items. A pretest of the questionnaire is conducted with three experts to assess logical consistency, ease of comprehension, adequacy of question item sequence, and contextual appropriateness. For specific item details, please see Supplementary Appendix 1. All the latent variables are measured using a five-point Likert scale, ranging from "strongly disagree" to "strongly agree."

3.2 Data collection

To enhance the validity of the research instrument, a presurvey was conducted. Based on the results of reliability and validity tests, the scale items were refined, leading to the development of the final questionnaire. The survey was administered to PHCPs in a pilot city of a medical consortium in Henan Province, China, from October 7, 2021, to October 30, 2021. The convenience sampling was chosen due to its practicality and feasibility within the context of the study. We selected participants from a diverse range of community health centers, township health centers, and village clinics to maximize the representativeness of the sample. The survey was distributed through the WenJuanXing platform using an online questionnaire. This platform not only made it convenient for participants to respond to the questionnaire but also ensured the integrity of the data by requiring all questions to be answered before submission. This feature prevented incomplete submissions and eliminated the possibility of resubmission, thereby maintaining the quality and integrity of the responses. Out of the 726 questionnaires distributed to participants, 655 were identified for inclusion in the study and used for analysis (participation rate 90.2%). The use of convenience sampling, although not probabilistic, aimed to capture a broad spectrum of PHCPs' experiences and perspectives, which we believe contributes to the

study's generalizability within the specific context of the medical consortium in Henan Province. This survey was approved by the Ethics Committee of the Xinxiang Medical University (reference number XYLL-2,017,032).

3.3 Data statistical analysis

The collected data were analyzed using statistical techniques, including descriptive statistics, confirmatory factor analysis (CFA), and structural equation modeling (SEM). The initial step involved exploring participant characteristics such as gender, age, educational background, and years of experience using the descriptive statistics tools provided by the SPSS software.

A CFA was conducted in the second step to determine the optimal measurement model. The model's reliability was assessed through calculations of Cronbach's alpha coefficient and the composite reliability (CR) values. The factor loadings and average variance extracted (AVE) were used to evaluate the convergent validity of the measurement model.

Subsequently, SEM was conducted using IBM SPSS Amos 22 software to examine the underlying assumptions in a structural model. SEM considers both observed and latent variables, providing a more comprehensive understanding of the interconnections between them. The fit of the SEM was evaluated through the use of various fit indices, including the χ^2/df-ratio, root mean square error of approximation (RMSEA), goodness-of-fit index (GFI), adjusted goodness-of-fit (AGFI), comparative fit index (CFI), incremental fit index (IFI), and Tucker–Lewis index (TLI). These indices are chosen for their ability to provide a nuanced assessment of the accuracy and meaningfulness of the SEM results, ensuring that the model's fit is rigorously evaluated from multiple perspectives. Furthermore, Within the framework of SEM, path coefficients were estimated, a process essential for delineating the relationships between variables within the research model. The estimation of these coefficients is a fundamental feature of SEM, justifying its application for inferring the strength and direction of relationships as per the theoretical framework. In aggregate, the utilization of SEM, complemented by descriptive statistics and confirmatory factor analysis (CFA), was selected to enable an exhaustive exploration of the relationships among variables. This methodological approach ensures robust and reliable findings, fitting the intricate nature of the research questions and providing a solid justification for the analytical techniques employed.

4 Results

4.1 Data collection

Demographic information for the sample of 655 participants is presented in Table 1. The sample consisted of 471 females (71.9%) and 184 males (28.1%). Within this group, 30.7% were aged 31 to 40, while 32.8% fell into the age range of 41 to 50. In terms of education, 64.3% had attained junior college level or below, while 33.4% held a bachelor's degree. Additionally, 40.8% of respondents had worked for 20 years or more. Based on the assessments from the health department, three levels of professional titles (i.e., junior, intermediate, and senior) are used to denote PHCPs' proficiency and seniority. Junior-level professional titles were held by 36.6% of PHCPs, with intermediate-level titles held by 29.8% and only 6.3% holding senior or above professional titles. In regard to social media usage, WeChat, a mainstream platform, was the most commonly used at 98%. The intra-organiz,ational social media platform was used at a rate of 25.5%, while the usage rate of other media was relatively low. It is worth noting that DingTalk is gradually attracting the attention of PHCIs.

TABLE 1 Demographic information.

Characteristics	Items	Statistics, *n* (%)
Gender	Male	184 (28.1)
	Female	471 (71.9)
Age (years)	<25	32 (4.9)
	26–30	100 (15.3)
	31–40	201 (30.7)
	41–50	215 (32.8)
	>50	107 (16.3)
Education	Junior college or below	421 (64.3)
	Bachelor's degree	219 (33.4)
	Master's degree and above	15 (2.3)
Years of experience	<1	12 (1.8)
	1–3	51 (7.8)
	4–10	139 (21.2)
	11–20	186 (28.4)
	>20	267 (40.8)
Professional title	No title	179 (27.3)
	Junior	240 (36.6)
	Intermediate	195 (29.8)
	Senior	41 (6.3)
Frequently used social media at work (Multiple choice)	WeChat	642 (98)
	QQ	131 (20)
	Weibo	19 (2.9)
	Intra-organizational social media platform (e.g., DingTalk)	167 (25.5)
	Others	13 (2)

4.2 Reliability and validity

The Cronbach's alpha coefficients for the scales of the social network, knowledge sharing, and job performance are all above 0.8. Additionally, Table 2 presents Cronbach's alpha coefficients and CR values for each intrinsic dimension of the three scales, which are also above 0.8, indicating that the scales exhibit high levels of internal consistency and reliability. The items' factor loadings were all above 0.6, and AVE for each construct was also above 0.6, demonstrating good convergent validity in the scales. Table 3 shows that the square root of each variable's AVE value is greater than its correlation coefficient with other dimensions, indicating satisfactory discriminant

TABLE 2 Construct reliability and convergent validity.

Variable	Construct	Items	Factor loading	Average variance extracted	Composite reliability	Cronbach's alpha
Social networks	Degree centrality	DC1	0.885	0.698	0.902	0.900
		DC2	0.907			
		DC3	0.813			
		DC4	0.726			
	Betweenness centrality	BC1	0.796	0.699	0.874	0.871
		BC2	0.904			
		BC3	0.803			
	Network heterogeneity	NH1	0.811	0.737	0.933	0.933
		NH2	0.862			
		NH3	0.875			
		NH4	0.887			
		NH5	0.854			
	Network tie strength	NTS1	0.859	0.718	0.884	0.883
		NTS2	0.892			
		NTS3	0.788			
Knowledge sharing	Explicit knowledge sharing	EKS1	0.875	0.790	0.918	0.919
		EKS2	0.893			
		EKS3	0.898			
	Tacit knowledge sharing	TKS1	0.944	0.888	0.960	0.966
		TKS2	0.947			
		TKS3	0.935			
Job performance	Task performance	TP1	0.867	0.792	0.919	0.918
		TP2	0.925			
		TP3	0.876			
	Interpersonal facilitation	IF1	0.901	0.847	0.943	0.942
		IF2	0.904			
		IF3	0.955			
	Job dedication	JD1	0.883	0.844	0.942	0.940
		JD2	0.963			
		JD3	0.909			

DC, degree centrality; BC, betweenness centrality; NH, network heterogeneity; NTS, network tie strength; EKS, explicit knowledge sharing; TKS, tacit knowledge sharing; TP, task performance; IF, interpersonal facilitation; JD, Job dedication.

validity. The correlations between the variables were analyzed, and it was found that there was no high correlation between the variables, as shown in Table 3. Hence, the survey instrument has good reliability and validity.

This study utilized Harman's single-factor test (62) to perform an exploratory factor analysis on the survey data. The first factor explaining 36.218% of the variance, less than 40%. Thus, it can be inferred that common method bias did not significantly affect the sample data collected in this study.

Table 4 shows that the model fits the data well, with a χ^2/df-ratio of less than 3 and an RMSEA of under 0.05, indicating reliability and robustness. In addition, the GFI, AGFI, CFI, IFI, and TLI all exceeded 0.9, suggesting a good fit between the model and the data. These high initial fit indices further support the model's suitability for explaining the observed relationships among the variables.

4.3 Path analysis

Figure 2 shows that social networks impacted knowledge sharing significantly. The unstandardized regression coefficients from degree centrality, betweenness centrality, network heterogeneity, and network tie strength to knowledge sharing were 0.147, 0.251, 0.145, and 0.27, respectively. All the p values were less than 0.001, which meant that social networks impacted knowledge sharing significantly. Degree centrality, network heterogeneity, and knowledge sharing significantly influenced job performance, with coefficients of 0.225, 0.039, and 0.032, respectively. However, betweenness centrality and network tie strength had no significant influence on job performance.

This study used bootstrapping as the repeated sampling method to produce statistical confidence intervals for indirect effects. Table 5 displays the statistically significant indirect effects of knowledge

TABLE 3 Discriminant validity.

	DC	BC	NH	NTS	EKS	TKS	TP	JD	IF
DC	0.836								
BC	0.380	0.836							
NH	0.278	0.387	0.858						
NTS	0.483	0.485	0.439	0.847					
EKS	0.360	0.460	0.356	0.462	0.889				
TKS	0.367	0.396	0.343	0.484	0.750	0.942			
TP	0.317	0.213	0.277	0.263	0.299	0.333	0.89		
JD	0.302	0.154	0.178	0.220	0.250	0.326	0.682	0.919	
IF	0.341	0.241	0.247	0.302	0.317	0.367	0.774	0.751	0.92

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$. KS, knowledge sharing; JP, job performance.

TABLE 4 Goodness-of-fit indices of the structural equation model.

Indices	χ^2/df	RMSEA	GFI	AGFI	CFI	IFI	TLI
Criteria	<3	<0.05	>0.9	>0.9	>0.9	>0.9	>0.9
Value	2.232	0.043	0.917	0.900	0.974	0.974	0.970

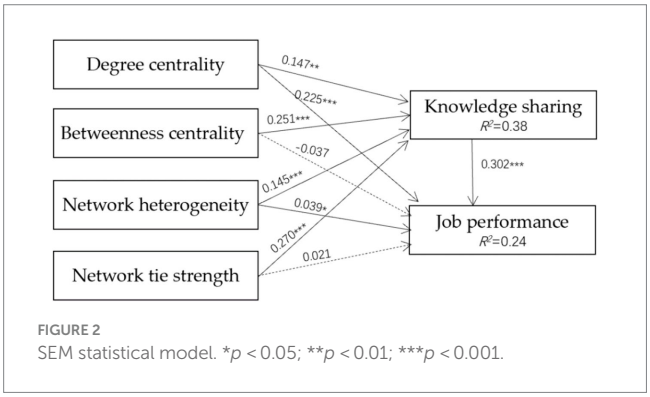


FIGURE 2
SEM statistical model. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

sharing in the paths from degree centrality, betweenness centrality, network heterogeneity, and network tie strength to job performance. For all four paths, the values of the lower bound and upper bound of the confidence intervals were not across 0, which meant that an indirect effect existed.

5 Discussion

5.1 Principal findings and explanations

Our study reveals the significant influence of social networks on knowledge sharing and job performance among PHCPs in China. Specifically, degree centrality and network heterogeneity were found to have substantial effects on knowledge sharing, which in turn positively impacts job performance. This finding aligns with a recent study on hypertension management teams, which demonstrated that in-closeness centrality of advice networks positively affects task performance (12). Interestingly, while betweenness centrality and network tie strength did not directly impact job performance, they

TABLE 5 Indirect effects of the estimated SEM using bootstrapping (2000 replications).

Indirect effects	Product of coefficients			Bootstrapping procedure
	Est.	S.E.	*p* Value	CI 95%
DC→KS→JP	0.031	0.015	0.006	(0.009, 0.069)
BC→KS→JP	0.041	0.013	0.000	(0.021, 0.076)
NH→KS→JP	0.032	0.016	0.010	(0.008, 0.071)
NTS→KS→JP	0.064	0.026	0.001	(0.026, 0.134)

significantly influenced knowledge sharing. This relationship highlights the complex nature of social networks in healthcare settings, where different dimensions of centrality contribute to various aspects of professional interactions. Recent research suggests that betweenness centrality is a key measure of node importance in networks (63), which in our context, corresponds to the crucial role certain PHCPs play in facilitating knowledge flow.

Our study confirms that knowledge sharing mediates the relationship between social networks and job performance. This finding is consistent with research demonstrating that knowledge integration is significantly related to patient-centered teamwork and team performance in healthcare settings (64). The mediating role of knowledge sharing underscores its importance as a linking mechanism between the structural attributes of social networks and job performance within PHC institutions. PHCPs who actively engage in knowledge sharing are more likely to excel in their roles, highlighting the necessity of encouraging and facilitating knowledge exchange within healthcare settings (65). This aligns with previous research emphasizing the importance of fostering a knowledge-sharing culture in healthcare organizations (66).

The cultural context of Chinese society profoundly shapes the dynamics of social networks and knowledge sharing among PHCPs. The principles of collectivism, the importance of relational values (Guanxi), and the concept of face (social reputation and dignity) are deeply embedded in professional and social behaviors (67). In a collectivist culture, the emphasis on group harmony and team cooperation is paramount, which may explain the strong influence of degree centrality on knowledge sharing and job performance (68). Our findings resonate with research that found

cultural contingencies significantly influence knowledge seeking and providing behaviors (69). PHCPs with high degree centrality, who maintain closer relationships with a broader array of colleagues, are likely to be more actively involved in various tasks. This increased involvement allows them to access diverse information and resources, optimizing workload distribution and task coordination. Their prominent network position also enhances their social reputation or "face," fostering a supportive and cooperative environment among colleagues. Consequently, this culturally embedded degree centrality enhances individual efficiency, integrates resources, promotes knowledge sharing, and subsequently improves overall job performance.

The study highlights the predominant use of WeChat and DingTalk among PHCPs for social media communication. WeChat, with a 98% usage rate, is favored for its ubiquity in daily life, facilitating informal communication and tacit knowledge exchange. Its real-time, flexible communication features are crucial for sharing experiences, discussing complex clinical information, and collaborating on patient cases. In contrast, DingTalk, used by 25.5% of PHCPs, is better suited for formal knowledge dissemination. Its enterprise features support structured communication, training, and standardized information sharing, making it valuable for formal documentation and organized knowledge transfer. These platforms foster proactive and spontaneous knowledge sharing behaviors, which in turn contribute positively to patient well-being. This dual platform approach aligns with findings on the adoption of social media by clinicians for professional knowledge sharing and social networking (38). Emerging technologies such as artificial intelligence, augmented reality, and blockchain have the potential to enhance communication, improve data security, and facilitate more dynamic and interactive knowledge sharing among healthcare professionals (70). These advancements could further strengthen social networks by making them more efficient and resilient, ultimately improving the job performance of PHCPs.

5.2 Theoretical and practical implications

This study enhances social network theory and knowledge management literature in healthcare by revealing the complex interplay between social network centrality and job performance through knowledge sharing, particularly in the context of Chinese primary healthcare, highlighting the crucial role of knowledge exchange mechanisms in driving professional performance. Thereby bridging theoretical understanding with practical implications. The findings of this study carry practical significance for primary healthcare managers and policymakers. To enhance the job performance of PHCPs, several managerial actions could be considered. First, healthcare organizations should actively promote the development of strong social networks among PHCPs, acknowledging the importance of guanxi (social connections) within the Chinese context. This can be facilitated through team-building activities (71), collaborative projects (72), and the utilization of social media platforms that support professional networking. Second, a culture that encourages and rewards knowledge sharing (73) among PHCPs should be cultivated. Barriers to social media-based knowledge sharing, such as knowledge codification costs, fear of losing intellectual capital, and challenges in building digital trust need to be addressed (41). To ensure sustainability and effectiveness, healthcare organizations can implement incentive mechanisms that emphasize both individual and organizational benefits, provide training on digital literacy for effective knowledge-sharing practices, and invest in user-friendly social media tools to enhance participation in knowledge exchange activities. Third, organizations should balance degree centrality and network heterogeneity, as an overemphasis on centralization may lead to information bottlenecks (74). Managers should aim to create networks that balance centrality and diversity. Given the widespread use of platforms such as WeChat and DingTalk among Chinese PHCPs, integrating these platforms into knowledge-sharing strategies is recommended due to their effectiveness in facilitating communication and collaboration (75). Lastly, continuous investment in training and career development opportunities for PHCPs is crucial (76). An effective approach would be to integrate online learning with social media, thereby enhancing the overall knowledge quality of the PHCP social network.

5.3 Limitations and future directions

This study has several limitations. First, it relied on subjective self-assessments, potentially introducing bias. Future research should incorporate objective data and include evaluations from colleagues or superiors to enhance cross-validation. Second, the use of cross-sectional data constrains causal inference. Future studies should employ longitudinal or panel data to elucidate causal mechanisms more effectively. Third, the sample was limited to a single city in Henan Province, affecting generalizability. Future research should adopt multicenter designs and larger, more diverse samples to improve the representativeness and applicability of the findings. Fourth, this study examined social networks' impact on job performance from a static perspective, disregarding their dynamic nature and sustainability of knowledge-sharing over time. Future research should employ dynamic network analysis to capture the evolution of social network structures and their effects on knowledge sharing and job performance. Lastly, this study did not address factors such as information overload, ethical risks, trust within social networks, and the digital literacy and leadership of primary healthcare professionals due to its specific research focus. However, the rapid advancement of internet technology and social media in healthcare will bring significant changes and challenges. Future research should explore these issues to effectively navigate the complexities introduced by these technological advancements.

6 Conclusion

This study developed a research model of the social networks, knowledge sharing, and job performance of PHCPs in a social media environment. It was confirmed that social networks, as indicated by degree centrality, betweenness centrality, network heterogeneity, and network tie strength, affect job performance through knowledge sharing by empirical analysis. This study not only fills in the gaps in the literature that knowledge sharing acts

as an intermediary between social networks and job performance in the healthcare field but also provides many implications for promoting knowledge sharing among PHCPs and for improving their work performance.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to XW, wxbtj@hust.edu.cn.

Ethics statement

The Ethics Committee of Xinxiang Medical University waived the requirement for informed consent. All data used in this study were approved by the Healthy Central Plains Research Institute of Xinxiang Medical University (reference number XYLL-2017032). All methods employed in this study were conducted in accordance with relevant guidelines and regulations.

Author contributions

XW: Conceptualization, Writing – original draft. SH: Data curation, Supervision, Writing – review & editing. QL: Data curation, Investigation, Writing – review & editing. YL: Data curation, Writing – review & editing. HW: Investigation, Writing – review & editing. ZL: Supervision, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This research was supported by grants from the National Natural Science Foundation of China (No. 71874059).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2024.1324939/full#supplementary-material

References

1. Dong Y, Yang X, Fang P, Pan Z, Luo Z. Have the pilot county hospitals' service capability been improved since the healthcare reform? An analysis of 370 hospitals in China. *Iran J Public Health*. (2019) 48:474–83. doi: 10.18502/ijph.v48i3.891

2. Liu S, Lin J, He Y, Xu J. The service capability of primary health institutions under the hierarchical medical system. *Healthcare*. (2022) 10:335. doi: 10.3390/healthcare10020335

3. Li X, Lu J, Hu S, Cheng KK, De Maeseneer J, Meng Q, et al. The primary health-care system in China. *Lancet*. (2017) 390:2584–94. doi: 10.1016/S0140-6736(17)33109-4

4. Li X, Zhang L, Li Z, Tang W. Patient choice and willingness toward gatekeepers as first-contact medical institutions in chinese tiered healthcare delivery system: a cross-sectional study. *Front Public Health*. (2021) 9:665282. doi: 10.3389/fpubh.2021.665282

5. Katz FM, Snow R. Assessing health workers' performance: a manual for training and supervision. Geneva, Switzerland: World Health Organization (1980) p. 13–4.

6. Spagnoli P, Haynes NJ, Kovalchuk LS, Clark MA, Buono C, Balducci C. Workload, workaholism, and job performance: uncovering their complex relationship. *Int J Environ Res Public Health*. (2020) 17:17. doi: 10.3390/ijerph17186536

7. Liu D, Yang X, Zhang C, Zhang W, Tang Q, Xie Y, et al. Impact of job satisfaction and social support on job performance among primary care providers in Northeast China: a cross-sectional study. *Front Public Health*. (2022) 10:884955. doi: 10.3389/fpubh.2022.884955

8. Anselmann V, Mulder RH. Transformational leadership, knowledge sharing and reflection, and work teams' performance: a structural equation modelling analysis. *J Nurs Manag*. (2020) 28:1627–34. doi: 10.1111/jonm.13118

9. Curado C, Santos R. Transformational leadership and work performance in health care: the mediating role of job satisfaction. *Leadership Health Serv*. (2021) 35:160–73. doi: 10.1108/LHS-06-2021-0051

10. Zeng Z, Deng Q, Liu W. Knowledge sharing of health technology among clinicians in integrated care system: the role of social networks. *Front Psychol*. (2022) 13:6736. doi: 10.3389/fpsyg.2022.926736

11. Li H, Yuan B, Wang D, Meng Q. Motivating factors on performance of primary care workers in China: a systematic review and meta-analysis. *BMJ Open*. (2019) 9:e028619. doi: 10.1136/bmjopen-2018-028619

12. Xia Q, Xu Y, Liu X, Liu Y, Wu J, Zhang M. Effects of social networks on job performance of individuals among the hypertension management teams in rural China. *Healthcare*. (2023) 11:2218. doi: 10.3390/healthcare11152218

13. Sumayyia MD, Al-Madaney MM, Almousawi FH. Health information on social media. Perceptions, attitudes, and practices of patients and their companions. *Saudi Med J*. (2019) 40:1294–8. doi: 10.15537/smj.2019.12.24682

14. Ukoha C, Stranieri A. Criteria to measure social media value in health care settings: narrative literature review. *J Med Internet Res*. (2019) 21:e14684. doi: 10.2196/14684

15. Ahlqvist T, Bäck A, Halonen M, Heinonen S. Social media roadmaps: exploring the futures triggered by social media. Espoo: VTT Technical Research Centre of Finland (2008).

16. Sindermann C, Yang H, Yang S, Elhai JD, Montag C. Willingness to accept (WTA), willingness to pay (WTP), and the WTA/WTP disparity in chinese social media platforms: descriptive statistics and associations with personality and social media use. *Acta Psychol*. (2022) 223:103462. doi: 10.1016/j.actpsy.2021.103462

17. Wang H, Xiao Y, Wang H, Zhang H, Chen X. "who knows me understands my needs": the effect of home-based telework on work engagement. *Psychol Res Behav Manag*. (2023) 16:619–35. doi: 10.2147/PRBM.S402159

18. Venegas-Vera AV, Colbert GB, Lerma EV. Positive and negative impact of social media in the COVID-19 era. *Rev Cardiovasc Med*. (2020) 21:561–4. doi: 10.31083/j.rcm.2020.04.195

19. Pierce BS, Perrin PB, Dow AW, Dautovich ND, Rybarczyk BD, Mishra VK. Changes in physician telemedicine use during COVID-19: effects of practice setting, demographics, training, and organizational policies. *Int J Environ Res Public Health*. (2021) 18:18. doi: 10.3390/ijerph18199963

20. Berkman LF, Clark C. Neighborhoods and networks: the construction of safe places and bridges In: I Kawachi and LF Berkman, editors. Neighborhoods and health. New York: Oxford University Press (2003) p. 288–302.

21. Tasselli S. Social networks of professionals in health care organizations: a review. *Med Care Res Rev*. (2014) 71:619–60. doi: 10.1177/1077558714557079

22. Ventola CL. Social media and health care professionals: benefits, risks, and best practices. *P&T* (2014) 39:491–9, 520.

23. Burt RS. The network structure of social capital. *Res Organ Behav*. (2000) 22:345–423. doi: 10.1016/S0191-3085(00)22009-1

24. Granovetter MS. The strength of weak ties. *AJS*. (1973) 78:1360–80. doi: 10.1086/225469

25. Freeman LC. A set of measures of centrality based on betweenness. *Sociometry*. (1977) 40:35. doi: 10.2307/3033543

26. Liu Y, Lu H, Chen C. Which are the vital factors of mobile personal health records applications that promote continued usage? A perspective on technology fit and social capital. *Digit Health*. (2023) 9:205520762311812. doi: 10.1177/20552076231181216

27. Wasserman S, Faust K. Social network analysis: Methods and applications. Cambridge: Cambridge University Press (1994).

28. Uddin S, Hossain L, Hamra J, Alam A. A study of physician collaborations through social network and exponential random graph. *BMC Health Serv Res*. (2013) 13:234. doi: 10.1186/1472-6963-13-234

29. Bizzi L. The problem of employees' network centrality and supervisors' error in performance appraisal: a multilevel theory. *Hum Resour Manag*. (2018) 57:515–28. doi: 10.1002/hrm.21880

30. Ahuja MK, Carley KM, Galletta DF. Individual centrality and performance in virtual R&D groups: an empirical study. *Manag Sci*. (2003) 49:21–38. doi: 10.1287/mnsc.49.1.21.12756

31. Cai M, Wang W, Cui Y, Stanley HE. Multiplex network analysis of employee performance and employee social relationships. *Physica A*. (2018) 490:1–12. doi: 10.1016/j.physa.2017.08.008

32. Sparrowe RT, Liden RC, Wayne SJ, Kraimer ML. Social networks and the performance of individuals and groups. *Acad Manag J*. (2001) 44:316–25. doi: 10.2307/3069458

33. Lee JK, Choi J, Kim C, Kim Y. Social media, network heterogeneity, and opinion polarization. *J Commun*. (2014) 64:702–22. doi: 10.1111/jcom.12077

34. Kim Y, Hsu S, de Zúñiga HG. Influence of social media use on discussion network heterogeneity and civic engagement: the moderating role of personality traits. *J Commun*. (2013) 63:498–516. doi: 10.1111/jcom.12034

35. Brashears ME, Quintane E. The weakness of tie strength. *Soc Networks*. (2018) 55:104–15. doi: 10.1016/j.socnet.2018.05.010

36. Reagans R. Close encounters: analyzing how social similarity and propinquity contribute to strong network connections. *Organ Sci*. (2011) 22:835–49. doi: 10.1287/orsc.1100.0587

37. Bian Y. The prevalence and the increasing significance of guanxi. *China Q*. (2018) 235:597–621. doi: 10.1017/S0305741018000541

38. Asfaw TT, Mekonnen BY. Knowledge sharing by clinicians using social media: a case study in Ethiopia. *Afr J Sci Technol Innov Dev*. (2022) 14:630–41. doi: 10.1080/20421338.2021.1883413

39. Bock G, Zmud RW, Kim Y, Lee J. Behavioral intention formation in knowledge sharing: examining the roles of extrinsic motivators, social-psychological forces, and organizational climate. *MIS Q*. (2005) 29:87–111. doi: 10.2307/25148669

40. Panahi S, Watson J, Partridge H. Social media and tacit knowledge sharing: developing a conceptual model. *World Acad Sci Eng Technol*. (2012) 64:1095–102.

41. Ahmed YA, Ahmad MN, Ahmad N, Zakaria NH. Social media for knowledge-sharing: a systematic literature review. *Telemat Inform*. (2019) 37:72–112. doi: 10.1016/j.tele.2018.01.015

42. Baek SI, Bae SH. The effect of social network centrality on knowledge sharing. *J Serv Sci Res*. (2019) 11:183–202. doi: 10.1007/s12927-019-0009-2

43. Liu X, Jiang S, Sun M, Chi X. Examining patterns of information exchange and social support in a web-based health community: exponential random graph models. *J Med Internet Res*. (2020) 22:e18062. doi: 10.2196/18062

44. Markham MJ, Gentile D, Graham DL. Social media for networking, professional development, and patient engagement. *Am Soc Clin Oncol Educ Book*. (2017) 37:782–7. doi: 10.1200/EDBK_180077

45. Zhao J, Guo T, Shang S, Wang M. Work along both lines: the positive impact of work-based social media use on job performance. *Int J Environ Res Public Health*. (2021) 18:18. doi: 10.3390/ijerph182111578

46. Awada H. An investigation of the relationship between organizational structure, tie strength and tacit knowledge sharing. *Kidmore End*. (2019) 1:13–24. doi: 10.32038/JBSO.2019.01.02

47. Levin DZ, Cross R. The strength of weak ties you can trust: the mediating role of trust in effective knowledge transfer. *Manag Sci*. (2004) 50:1477–90. doi: 10.1287/mnsc.1030.0136

48. Kwahk K, Park D. The effects of network sharing on knowledge-sharing activities and job performance in enterprise social media environments. *Comput Hum Behav*. (2016) 55:826–39. doi: 10.1016/j.chb.2015.09.044

49. Lee SY, Lee SW. Facebook use and job performance: the mediating effects of social capital, knowledge sharing, and job satisfaction. *Int J Hum Comp Interact*. (2022) 38:1359–74. doi: 10.1080/10447318.2021.2002045

50. Sirous P, Jason W, Helen P. Conceptualising social media support for tacit knowledge sharing: physicians' perspectives and experiences. *J Knowl Manag*. (2016) 20:344–63. doi: 10.1108/JKM-06-2015-0229

51. Zhao Y, Wang X, Chen C, Shi K. A moderated mediation model of workplace ostracism and task performance. *Chin Manag Stud*. (2019) 14:51–67. doi: 10.1108/CMS-10-2018-0716

52. Myers CG, Kudsi Y, Ghaferi AA. Surgeons are using social media to share and learn new skills. (2017). Available at: https://hbr.org/2017/10/surgeons-are-using-social-media-to-share-and-learn-new-skills (Accessed September 20, 2024).

53. Rafique GM, Mahmood K. Impact of knowledge sharing at work place on individual work performance of nurses in Pakistan. *Inf Discov Deliv*. (2021) 49:335–45. doi: 10.1108/IDD-07-2020-0078

54. Bhuiyan MN, Medina-Inojosa JR, Croghan IT, Marcelin JR, Ghosh K, Bhagra A. Internal medicine physicians and social media: knowledge, skills, and attitudes. *J Prim Care Community Health*. (2020) 11:921852610. doi: 10.1177/2150132720969022

55. Freeman LC. Centrality in social networks conceptual clarification. *Soc Networks*. (1978) 1:215–39. doi: 10.1016/0378-8733(78)90021-7

56. Marsden PV. Core discussion networks of americans. *Am Sociol Rev*. (1987) 52:122. doi: 10.2307/2095397

57. Harrison DA, Price KH, Gavin JH, Florey AT. Time, teams, and task performance: changing effects of surface-and deep-level diversity on group functioning. *Acad Manag J*. (2002) 45:1029–45. doi: 10.2307/3069328

58. Bock GW, Kim Y. Breaking the myths of rewards: an exploratory study of attitudes about knowledge sharing. *Inf Resour Manag J*. (2002) 15:14–21. doi: 10.4018/irmj.2002040102

59. Borman WC, Motowidlo S. Expanding the criterion domain to include elements of contextual performance. In: N Schmitt and WC Borman, editors. Personnel Selection in Organizations. San Francisco, CA: Jossey-Bass (1993) p. 71–98.

60. Borman WC, Motowidlo SJ. Task performance and contextual performance: the meaning for personnel selection research. *Hum Perform*. (1997) 10:99–109. doi: 10.1207/s15327043hup1002_3

61. Van Scotter JR, Motowidlo SJ. Interpersonal facilitation and job dedication as separate facets of contextual performance. *J Appl Psychol*. (1996) 81:525–31. doi: 10.1037/0021-9010.81.5.525

62. Aguirre-Urreta MI, Hu J. Detecting common method bias: performance of the harman's single-factor test. *ACM SIGMIS Database*. (2019) 50:45–70. doi: 10.1145/3330472.3330477

63. Xiang N, Wang Q, You M. Estimation and update of betweenness centrality with progressive algorithm and shortest paths approximation. *Sci Rep*. (2023) 13:17110. doi: 10.1038/s41598-023-44392-0

64. Körner M, Lippenberger C, Becker S, Reichler L, Müller C, Zimmermann L, et al. Knowledge integration, teamwork and performance in health care. *J Health Organ Manag*. (2016) 30:227–43. doi: 10.1108/JHOM-12-2014-0217

65. Yousra H, Ali Z, Issa S, Justin ZZ. Managing knowledge workers in healthcare context: role of individual and knowledge characteristics in physicians' knowledge sharing. *Ind Manage Data Syst*. (2021) 121:381–408. doi: 10.1108/IMDS-02-2020-0097

66. Sabeeh Z, Syed Mustapha S, Mohamad R. Healthcare knowledge sharing among a community of specialized physicians. *Cogn Tech Work*. (2018) 20:105–24. doi: 10.1007/s10111-017-0453-z

67. Jackson LA, Wang J. Cultural differences in social networking site use: a comparative study of China and the United States. *Comput Hum Behav*. (2013) 29:910–21. doi: 10.1016/j.chb.2012.11.024

68. Xie B, Li M. Coworker guanxi and job performance: based on the mediating effect of interpersonal trust. *Technol Forecast Soc Change*. (2021) 171:120981. doi: 10.1016/j.techfore.2021.120981

69. Venkatesh V, Davis FD, Zhu Y. A cultural contingency model of knowledge sharing and job performance. *J Bus Res*. (2022) 140:202–19. doi: 10.1016/j.jbusres.2021.07.042

70. Paul TS. Emerging technologies: factors influencing knowledge sharing. *World J Educ Res*. (2022) 9:68–74. doi: 10.22158/wjer.v9n2p68

71. Jaruseviciene L, Liseckiene I, Valius L, Kontrimiene A, Jarusevicius G, Lapão LV. Teamwork in primary care: perspectives of general practitioners and community nurses in Lithuania. *BMC Fam Pract*. (2013) 14:118. doi: 10.1186/1471-2296-14-118

72. Prado AM, Pearson AA, Bertelsen NS, Pagán JA. Connecting healthcare professionals in central america through management and leadership development: a social network analysis. *Glob Health*. (2020) 16:34. doi: 10.1186/s12992-020-00557-4

73. Gagné M, Tian AW, Soo C, Zhang B, Ho KSB, Hosszu K. Different motivations for knowledge sharing and hiding: the role of motivating work design. *J Organ Behav*. (2019) 40:783–99. doi: 10.1002/job.2364

74. Gilfoyle M, Salsberg J, Mccarthy M, Macfarlane A, Maccarron P. Exploring the multidimensionality of trust in participatory health partnerships - a network approach. *Front Public Health*. (2022) 10:925402. doi: 10.3389/fpubh.2022.925402

75. Chan WS, Leung AY. Use of social network sites for communication among health professionals: systematic review. *J Med Internet Res*. (2018) 20:e117. doi: 10.2196/jmir.8382

76. Li X, Krumholz HM, Yip W, Cheng KK, De Maeseneer J, Meng Q, et al. Quality of primary health care in China: challenges and recommendations. *Lancet*. (2020) 395:1802–12. doi: 10.1016/S0140-6736(20)30122-7

frontiers | Frontiers in Medicine

TYPE Original Research
PUBLISHED 17 December 2024
DOI 10.3389/fmed.2024.1425659

OPEN ACCESS

EDITED BY
Octavian Dospinescu,
Alexandru Ioan Cuza University, Romania

REVIEWED BY
Nirmala Rege,
King Edward Memorial Hospital and Seth Gordhandas Sunderdas Medical College, India
Ganesh Kamath Mulki,
Manipal University College Malaysia, Malaysia

*CORRESPONDENCE
Nida Gull
✉ nida@hnu.edu.cn;
✉ nidagull3333@gmail.com

RECEIVED 30 April 2024
ACCEPTED 27 November 2024
PUBLISHED 17 December 2024

CITATION
Ashraf MA, Tsegay SM, Gull N, Saeed M and Dawood H (2024) The role of blended learning in improving medical students' academic performance: evidence from Pakistan.
Front. Med. 11:1425659.
doi: 10.3389/fmed.2024.1425659

The role of blended learning in improving medical students' academic performance: evidence from Pakistan

Muhammad Azeem Ashraf[1], Samson Maekele Tsegay[2], Nida Gull[3]*, Muneeba Saeed[4] and Hussain Dawood[5]

[1]Institute of Educational Sciences, Hunan University, Changsha, China, [2]School of Education, Anglia Ruskin University, Cambridge, United Kingdom, [3]Business School, Hunan University, Changsha, China, [4]School of Management Sciences, Quaid-i-Azam University, Islamabad, Pakistan, [5]School of Computing, Skyline University College, Sharjah, United Arab Emirates

Objective: The study examines the role of blended learning in improving medical students' academic performance through self-regulatory learning and technological competence and identifies the moderating role of perceived institutional support in the relationships between self-regulatory learning, perceived teacher credibility, technological competencies, and academic performance.

Methods: The study was based on behavioral learning theory as a theoretical framework, and an adapted questionnaire was used to collect the data. In total, 275 medical students participated in the study, and the data was analyzed using structural equation modeling techniques with SmartPLS.

Results: The results indicate that self-regulatory learning significantly affects student academic performance and mediates the role of teachers' credibility and technological competencies. Furthermore, perceived institutional support is a significant moderator in the relationship between self-regulated learning, technological competencies, and teacher credibility.

Conclusion: The study highlights the importance of self-regulated learning in students' academic achievement. Moreover, it suggests that educational institutions should advance teachers' competence and encourage collaborative learning to enhance students' learning, motivation, and academic performance.

KEYWORDS

blended learning, self-regulated learning, academic performance, technological competence, teachers' credibility, perceived institutional support, medical education

Introduction

The impact of blended learning on medical students' performance is complex, as it can cause positive or negative consequences depending on factors such as teachers' technological and teaching skills (1–3). The complex nature of blended learning is more visible in medical education, a profession that might need more face-to-face contact and practical work experiences. Yet, with the advancement of information and communication technologies (ICT), the rapid institutional transition to blended learning has created new possibilities and challenges for students' academic development (4, 5). Blended learning allowed students to balance academic and extra-curricular responsibilities (6, 7). Dziuban and Picciano (8) emphasized that participating in blended learning lectures and making use of digital resources help medical students develop the technological skills required to manage and cope with today's data-driven society. In addition, blended learning promotes self-regulatory learning behavior of students accountable for their development and attendance (2).

Blended learning strategies have been extensively studied in education, resulting in numerous and some contradicting research findings (9, 10). Nevertheless, less attention has been given to research on self-regulatory learning under blended learning (3, 11). Gómez et al. (12) describe self-regulatory learning as a dynamic process in which learners establish learning goals and consciously monitor, regulate, and control their cognition, intentions, and behavior. Research also shows that teachers' effectiveness is the most critical factor in shaping learners' achievements (13) and influencing their academic performance (14). Several studies have explored effective teacher characteristics and concluded that teacher quality is the strongest predictor of academic performance (15).

In addition, research further suggests that instructors should give students enough direction and support to grasp and successfully engage in blended learning classes (16). Instructors must provide students with adequate direction and support to effectively engage in blended learning environments. This requirement highlights the importance of instructors and students possessing strong technological skills to participate in blended classrooms successfully (7). Based on these findings, this study investigates the effect of self-regulated learning on students' academic performance in blended learning environments, precisely in medical education. Additionally, this research aims to identify the features and approaches that facilitate effective blended instruction and promote positive student outcomes.

Existing research underscores the significance of teachers' credibility—defined as students' belief in their ability to learn from a given teacher—and technological competence in motivating students and optimizing the use of blended learning (17–19). In this context, perceived institutional support, such as teachers' credibility and technical skills, strongly predicts students' satisfaction and commitment to self-regulatory learning (4, 20). Medical education demands highly skilled educators who can effectively integrate theoretical knowledge with practical application, shaping students' expectations, motivation, and satisfaction (7).

While blended learning has been shown to enhance educational outcomes (18, 19), it has also raised concerns about the academic performance of medical students. However, adopting a learner-centered approach, supported by empirical evidence, has been found to positively impact educational achievements in blended learning environments (21). Masnadi (22) further emphasizes that, like other disciplines, medical science education requires competent and credible teachers to implement successful blended learning strategies. These observations suggest that multiple factors influence the effectiveness of blended learning in medical education.

Although prior studies have explored the general benefits and challenges of blended learning, limited research focuses on the interplay between self-regulatory learning, teacher credibility, and technological competence in medical education. Furthermore, the moderating role of perceived institutional support in enhancing these relationships remains underexplored. Therefore, this study aims to provide new insights into optimizing blended learning strategies for medical students by addressing these gaps. The following research questions guide the study.

(a) How does self-regulatory learning impact medical students' academic performance in blended learning environments?
(b) How do perceived teacher credibility and technological competencies mediate the relationship between self-regulatory learning and student academic achievement?
(c) What is the moderating role of perceived institutional support in the relationships between self-regulatory learning, perceived teacher credibility, technological competencies, and academic performance?

This study contributes to understanding the impact of self-regulatory learning on medical students' academic achievements in blended learning settings. It also advances knowledge by examining the mediating roles of teacher credibility and technological competence while exploring the moderating effect of perceived institutional support. By doing so, the research offers practical recommendations for enhancing blended learning outcomes in medical education.

Theoretical framework and hypothesis development

Behavioral learning theory

This paper is based on behavioral learning theory. Bandura (23) created behavioral learning theory to encourage intrinsic motivation and creative learning. In line with this, Anthonysamy et al. (24) initiated the student participation theory, describing that the physiological and psychological energy that participates in the learning process establishes the primary factor for students to learn. It suggests that factors such as students' attitudes, emotions, and behaviors toward teachers affect the degree of student intention to use technology (25).

Behaviorist learning theory understands the "essence" of learning as learners showing specific behavioral responses to motivations (26). Learning occurs when the learner presents an expected or appropriate response to a certain momentum. This theory argues that teaching and learning refer to learners accepting instruction from teachers to achieve expected learning goals and externally manifesting expected learning behaviors. Therefore, learning based on biobehavioral learning theory belongs to receptive learning, and its learning basis is the metaphor of transmitting information from teachers to students. Teachers convey to students what students understand, allowing students to learn something.

To improve the influence of communication, teachers should design a learning environment to enhance the transmission of information. Teachers should construct a teaching environment that allows learners to respond to inducements as they think appropriate, thereby maximizing learners' active actions, and learning is equivalent to changing the form or number of observed actions (5). Therefore, this study's understanding of learning motivation is mainly based on biobehavioral learning theory (27), which provides students with learning stimulation through technology or strategies. Teachers can encourage or strengthen students' desired learning behaviors in specific learning situations.

Self-regulatory learning and student learning outcome

The growing use of Internet technologies in education has resulted in new learning paradigms, such as self-regulatory

learning (28). Self-regulated learning is a multifaceted term that includes various aspects of human functioning, such as motivation, cognition, behavior, emotion, and metacognition (24). Many modern theorists consider an individual's capacity to plan, implement, and consistently adapt or enhance various self-control strategies as a crucial aspect of the dynamic and flexible self-regulated learning process (29). It is challenging to propose a single definition for learning due to the various terminologies, such as e-learning, distributed learning, virtual learning, and distance learning over time. Müller et al. (4) have focused on creating an effective blended learning process that promotes positive outcomes.

Anthonysamy et al. (24) described self-regulatory learning through a blended learning approach comparing traditional face-to-face teaching and technology-mediated instructions. Hong et al. (30) referred to blended learning as a combination of classroom face-to-face studies with online learning. Similarly, Xu et al. (10) stated that blended learning is 'the range of possibilities presented by combining Internet and digital media with established classroom forms that require the physical co-presence of teacher and students'. The digital media and resources blended into traditional classes may include audio or video streaming, wikis, online forums, web-based applications, collaboration and communication tools, and virtual learning environments (31). The use of self-regulatory learning is deemed to bring changes to teaching and learning patterns in higher education, including class flexibility, student commitment, control, and review of learning (7). Xu et al. (10) investigated blended education's effect on students' medical-related learning outcomes and indicated that blended learning has a positive impact on both student interest and academic achievement. Su et al. (7) found that students who participated actively in blended medical lessons and effectively used digital resources outperformed their less-engaged peers in terms of learning results. In their recent study, Wu et al. (3) examined the impact of blended learning on the skill development of medical students and suggested that students need to develop and improve their medical skills. Rasheed et al. (32) found that active participation in blended medical training programs led to enhanced technical abilities among students, indicating a beneficial effect of blended learning on skill acquisition. Li and Wang (33) emphasized the significance of teacher support and guidance in enhancing student learning outcomes in blended education. Yang et al. (34) highlight the importance of teachers in facilitating student engagement and performance in blended learning through timely feedback, instructional support, and the establishment of a conducive learning environment. This indicates that several factors, including technology access, available resources, teacher-student interaction, and motivation, impact the efficacy of medical education. We propose the following hypotheses for further investigation in this study.

> *H1*: Self-regulated learning positively affects student learning outcomes under blended learning.
>
> *H2*: Self-regulated learning is significantly related to technology competence under blended learning.
>
> *H3*: Self-regulated learning is significantly related to teacher credibility under blended learning.

Mediation mechanism

Self-regulated learning, technological competencies, and student learning outcomes

Blended learning has become increasingly popular in academic settings due to its use of digital technologies and the Internet for educational purposes. Research has examined the correlation between self-regulated learning and student learning outcomes, resulting in a combination of positive and inconclusive results (33). A meta-analysis indicated that amalgamated learning yielded significant positive effects of moderate to large magnitude on student learning outcomes (35). The use of blended learning platforms may also improve students' academic outcomes because of their adaptability and ease of use (36).

Additionally, technical capabilities impact the connection between self-regulatory learning and student learning results. Students who are well-versed in technology can better use digital learning opportunities, such as online discussion forums, group projects, and databases (6). Similarly, students' technological competencies were positively related to their engagement and academic achievement in blended learning environments (32). The complex relationship between self-regulated learning, technological competence, and academic success must be acknowledged (13). Unequal access to technology and internet connection may lead to differences in students' learning results, as Costello et al. (37) discovered. Instructional strategy, educator involvement, student motivation, and technological resources should be considered to provide everyone a quality and fair education. This study proposed the following hypothesis:

> *H4*: Technological competence significantly mediates the relationship between self-regulated learning and student learning outcomes.

Self-regulatory learning, perceived teacher credibility, and student learning outcome

Blended learning transforms the configuration of learning resources and realizes the transformation from an entity to a network environment (38). Self-regulatory learning through digital platforms helps students feel safe and secure (). How students see a teacher's credibility might vary depending on factors, including their comfort level with blended learning and how they like to absorb information. Kuo and Tien (16) found that teachers' trustworthiness strongly influenced student engagement and learning outcomes in blended courses. According to Müller et al. (4), instructors may boost their credibility and student satisfaction by improving their communication skills, topic knowledge, and response speed. A feeling of presence and social interaction fostered through digital interactions might enhance teachers' credibility in the perception of their students. According to Xu et al. (10), instructors' trustworthiness and students' sense of care increase when instructors promptly and positively respond to students' questions and concerns in blended learning environments. The following hypotheses were advanced in this investigation based on the prior literature:

H5: Teachers' credibility mediates the relationship between self-regulated learning and student learning outcomes.

Moderating mechanism

Perceives institutional support as a moderator

Perceived institutional support refers to employees' general belief that the organization respects their contributions and cares about their wellbeing (39). According to Bernarto et al. (40), institutional support protects individuals from the harmful effects of job stress. Perceived support serves an informational function by providing individuals with enough information to help define, comprehend, and cope with stressful events. It works as a social companionship function that satisfies the need to be accompanied and have affiliation and distracts individuals from stress (41). Perceived support serves an instrumental function that provides material resources and services needed to help cope with stress (11).

The support provided within an organization significantly influences the acquisition and advancement of technical skills (24). Jehanzeb (41) identified that perceived institutional support and collaborative learning positively correlated to students' technological competencies within blended learning settings. This perspective supports empirical techniques like self-regulatory learning in top-down models, as opposed to qualitative interviews used in bottom-up models like the student approach to the learning model (10). Resource sharing, active participation in discussions, and assisting others can enhance technological competencies through exchanging knowledge and experiences (42). Wu et al. (3) found that well-designed blended learning platforms that promote social interactions and community building positively affect perceived institutional support and technological competencies. Versteijlen and Wals (15) identified a significant statistical correlation between perceived social support and technological competencies within blended learning environments. Additionally, Bamoallem and Altarteer (43) noted that students who receive support from organizations, engage in collaborative learning, and have access to well-designed blended learning environments are more likely to develop and demonstrate enhanced technological competencies.

In addition, there is a need to study the connection between teachers' legitimacy and perceived institutional support. Perceived institutional support encompasses individuals' belief in accessing supportive networks and resources, which can positively impact their wellbeing and academic achievements (44). Students' evaluations of their instructors' dependability, knowledge and qualifications are crucial in developing their credibility (10). Several studies have examined how students perceive their teachers' credibility within blended learning environments and its relationship to their perceived institutional support. Finn et al. (45) found a significant positive connection between students' evaluations of their teachers' credibility and their perceptions of the teachers' support. Additionally, Bruggeman et al. (46) highlighted a positive relationship between students' evaluation of teachers' institutional support and their credibility. In addition, this research suggests that the availability and quality of organizational learning resources positively influence students' perceptions of teachers' credibility in blended learning. Pishghadam et al. (47) identified that students' evaluation of their teachers' credibility, knowledge, competence, and communication abilities is higher when they perceive their teachers' organizational support. In blended learning context, students who receive greater organizational support from their instructors are more likely to regard them as credible and trustworthy (48). The integration of online communication tools, along with thoughtful design considerations in blended learning environments, can substantially shape students' perceptions of organizational support and their instructors' credibility (see Figure 1). This study proposed the following hypotheses.

H6: Perceived institutional support moderates the relationship between self-regulatory learning and technological competencies.

H7: Perceived institutional support moderates the relationship between self-regulatory learning and perceived teacher credibility.

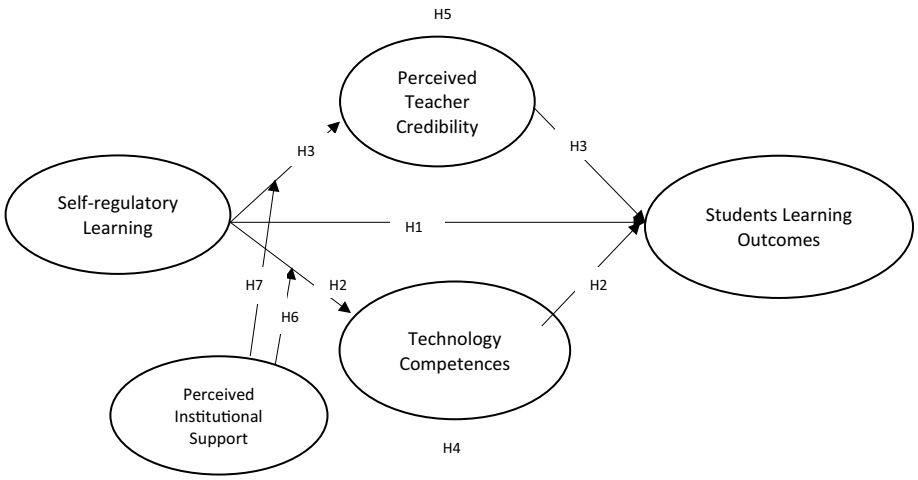


FIGURE 1
Study model.

Research methods

This study employed primary data from medical students in MBBS (Bachelor of Medicine, Bachelor of Surgery) programs at medical universities in Punjab province, Pakistan. The Punjab province, which is the most populous province in Pakistan, was selected purposely due to its medical universities and the researchers' familiarity with the area. Moreover, purposive sampling was used to select MBBS students from six medical universities located in Punjab province. We used a cross-sectional questionnaire based on MBBS students' self-administered survey. This study utilizes a convenience sampling method to reach the target participants with at least one month of blended learning experience. Additionally, convenience sampling, as a non-probability sampling method, allowed us to target participants considering their gender, education level, technology competence, and blended learning experiences (see Table 1). A total of 320 printed questionnaires were distributed to MBBS students in the last quarter of 2023, of which 275 questionnaires were returned with an 86% response rate.

Before the formal survey, participants were asked for consent before participating in the study. All participants were informed about the purpose of the study, their participation was voluntary, their information would be kept confidential, and the collected data would be used for research purposes only. However, the participants were not rewarded for their participation in the study. Ethical approval for this study was obtained from the university review committee (Hunan University, code 202301). All relevant units of selected medical universities were approached, and permission was obtained for data collection.

Measurement scale

The measurement scale comprises the instrument of study variables: blended learning, teachers' credibility, perceived institutional support, technological competencies, and students' learning outcomes. This study used adapted items from previous studies because they have been checked for reliability and validity (49). Seven items were adopted from the research instruments of Al-Omoush et al. (50) and Javier (51) to measure technological competencies. Ten items were adopted from Li-I Hsu (52) and Teven and McCroskey (53) to measure the participants' perceptions of their teachers' credibility. Eight items were adopted from San and Guo (54) to measure the perceived institutional support. Sixteen items were taken from Fuente et al. (55) to measure self-regulated learning, which includes three dimensions: planning (6 items), thoughtful learning (5 items), and study techniques (5 items). The learning outcomes were measured through 4 items from Ashraf et al. (18) using students' self-reported academic performance (from the previous year). The adopted items were modified to be more relevant and applicable in blended teaching

TABLE 1 Participants information.

Students		
	Frequency	Percentage
Gender		
Male	150	54.5
Female	125	45.5
Age (in years)		
18–20	85	30.9
21–23	112	40.7
24–25	52	18.9
Above 25	26	09.5
Education (level)		
First-year	70	25.5
Second-year	80	29.1
Third year	65	23.6
Fourth year	60	21.8
Technological competencies		
Basic computer skills	120	43.6
Intermediate computer skills	115	41.8
Advanced computer skills	40	14.5
Blended learning experience		
1 to 3 months	40	14.5
3–6 months	130	47.3
6–9 months	75	27.3
More than 9 months	30	10.9

background. Meanwhile, based on data from students, as this study measured the student's perceptions of their learning outcomes, the items were revised and adjusted accordingly. In addition, the study uses a 5-point Likert scale to measure the constructs, ranging from "strongly disagree" to "strongly agree."

In addition, before the formal study, the designed questionnaire was shared with three experts to determine the suitability and validity of the constructs in the medical universities in Pakistan. The questionnaire was revised based on their comments and suggestions. Furthermore, a pilot test was conducted with 25 participants to ensure the legibility of the survey questionnaire. Small changes, such as in questionnaire terminology and language used, were made based on the feedback.

Analysis

This study used the PLS-SEM (partial least rectangular structural equation modeling) method to analyze the data. PLS-SEM was chosen because it is appropriate for exploratory studies. The interpretation of PLS-SEM is also more straightforward and complex than that of covariance-based structural equation modeling (56, 57). SmartPLS was used to conduct the statistical analysis, and all the tests required for this research were performed with the help of this software. The direct effect, mediation, and moderation effects were tested to measure the relationships (58, 59).

Results

Participants background information

In total, 275 medical students enrolled in the medical universities participated in the study. Among the 275 participants, 150 (54.5%) were male and 125 (45.5%) were female students. Regarding the age range, 85 students (30.9%) were between 18–20 age, 112 (40.7%) were in 21–23 age, 52 (18.9%) were in 24–25 and 26 (09.5%) were above 25. In terms of the academic year, there were 70 first-year students (25.5%), 80 s-year students (29.1%), 65 third-year students (23.6%), and 60 fourth-year students (21.8%). Regarding technological competencies, 120 students (43.6%) reported having basic computer skills, 115 students (41.8%) indicated intermediate computer skills, and 40 students (14.5%) reported advanced computer skills. In terms of blended learning experience, 40 students (14.5%) had less than three months of experience, 130 students (47.3%) had three to six months of experience, 75 students (27.3%) had six to nine months of experience, and 30 students (10.9%) had more than nine months of online learning experience (Table 1).

Measurement model

The evaluation of the measurement model included an assessment of discriminant validity, convergent validity, and internal consistency measures, as outlined by Kern et al. (60). According to Hair et al. (61), a minimum factor-loading criterion of 0.6 is recommended. The internal consistency of constructs was evaluated using measures such as Composite Reliability (CR) and Cronbach Alpha. All values of Cronbach Alpha and Composite Reliability (CR) significantly meet the minimum acceptable criterion of 0.70. Moreover, the Average Variance Extracted (AVE) values exceeded the minimum requirement of 0.5, indicating the convergent validity of constructs. Table 2 displays the significant findings, such as factor loading, CR, AVE, and Cronbach Alpha.

The discriminant validity of the model is determined through the Fornell–Larcker criterion and Heterotrait-monotrait (HTMT) (61). The ability of one variable to viably differentiate itself from another is known as its "discriminant validity." Two different approaches, "Fornell-Larcker" and "cross-loading" statistical analysis, were used to determine the model's "discriminant validity." Table 3 illustrates that the square root of the AVE is higher than the correlation with other corresponding constructs (62). The top right diagonal indicates AVE's square root, which is greater than all other corresponding construct correlations.

Secondly, the discriminant validity is tested in this research using Heterotrait-monotrait (HTMT) ratio. The value HTMT ratios greater than 0.90 might be problematic for questioning discriminant validity (63). The findings in Table 4 show that all HTMT meet this limit (64), which confirms the discriminant validity of the research model.

Structural model

The structural model was examined after measuring the constructs' validity and reliability. As indicated in Table 5, the first step was to assess the constructs' coefficient of determination (R^2) and predictive relevance (Q^2). Next, the hypotheses testing was carried out using standardized coefficients. Standardized path coefficients were utilized to test the hypotheses. Additionally, the overall quality of the model is improved by each structural path, as recommended by Henseler et al. (63). R^2 values of 0.75, 0.50, and 0.25 for endogenous latent variables represent substantial, moderate, and weak effects, respectively,. According to the results, the R^2 values for Teacher Credibility, Technological Competencies, and Learning Outcome are 0.628, 0.755, and 0.664, respectively, indicating a strong predictive power of the model (65, 66). Additionally, the Stone-Geisser test (Q2) was employed to assess the predictive value of the dependent variables. A Q^2 value greater than zero is considered significant, while a Q^2 value less than zero indicates the unreliability of the predictive value (67, 68). However, all of the constructs indicate that the model has strong predictive power, as suggested by (66, 69).

Hypotheses testing

Following the assessment of goodness of fit, the hypotheses were further tested to determine the significance of the association. In this analysis, we use Bootstrapping at 5,000 with a replacement sample to assess the relative importance of associations (70). The study's findings revealed that a significant relationship between self-regulated learning and student learning outcomes is supported by ($\beta = 0.405$, $t = 2.784$, $p \leq 0.05$), showing a positive and significant relationship between self-regulated learning and student learning outcomes. The findings further revealed that self-regulated learning significantly impacts technological competence. The results show that self-regulated has a significant and positive impact on technological competence with

TABLE 2 Reliability and validity analysis.

Variables	Constructs	Factor loading	AVE	CR	α
Self-regulatory learning	SRL1	0.803	0.695	0.880	0.840
	SRL 2	0.720			
	SRL 3	0.758			
	SRL 4	0.776			
	SRL 5	0.786			
	SRL 6	0.788			
	SRL 7	0.714			
	SRL 8	0.713			
	SRL 9	0.827			
	SRL 10	0.723			
	SRL 11	0.702			
	SRL 12	0.876			
	SRL 13	0.784			
	SRL 14	0.756			
	SRL 15	0.826			
	SRL 16	0.886			
Perceived teacher credibility	PTC 1	0.835	0.648	0.859	0.793
	PTC 2	0.763			
	PTC 3	0.799			
	PTC 4	0.893			
	PTC 5	0.810			
	PTC 6	0.749			
	PTC 7	0.721			
	PTC 8	0.864			
	PTC 9	0.764			
	PTC 10	0.826			
Technologies competences	TC 1	0.752	0.738	0.788	0.721
	TC 2	0.713			
	TC 3	0.740			
	TC 4	0.706			
	TC 5	0.784			
	TC 6	0.758			
	TC 7	0.842			
Perceived institutional support	PIS 1	0.764	0.693	0.833	0.749
	PIS 2	0.702			
	PIS 3	0.846			
	PIS 4	0.742			
	PIS 5	0.826			
	PIS 6	0.804			
	PIS 7	0.786			
	PIS 8	0.790			
Students learning outputs	SLO 1	0.748	0.653	0.806	0.798
	SLO 2	0.832			
	SLO 3	0.790			
	SLO 4	0.768			

TABLE 3 Fornell & Larcker.

		1	2	3	4	5
1	Self-regulated learning	0.897				
2	Technological competency	0.383	0.861			
3	Teacher credibility	0.749	0.789	0.804		
4	Perceived institutional support	0.839	0.644	0.760	0.833	
5	Student learning outcome	0.730	0.743	0.662	0.689	0.805

TABLE 4 Heterotrait monotrait.

		1	2	3	4	5
1	Self-regulated learning	0.830				
2	Technological competency	0.621	0.807			
3	Teacher credibility	0.324	0.402	0.808		
4	Perceived institutional support	0.340	0.530	0.503	0.876	
5	Student learning outcome	0.201	0.630	0.230	0.503	0.850

TABLE 5 Predictive accuracy.

Constructs	R^2	Q^2
Perceived teacher credibility	0.628	0.342
Technological competencies	0.755	0.540
Learning outcome	0.664	0.402

TABLE 6 Structural model evaluation.

	Hypotheses	β	t-value	p-value	Decision
H1	Self-regulated learning->Learning outcome	0.405	2.784	0.001	Supported
H2	Self-regulated learning->Technology competence	0.856	14.813	0.000	Supported
H3	Self-regulated learning->Teacher credibility	0.042	2.085	0.030	Supported

($\beta = 0.856$, $t = 14.813$, $p \leq 0.05$), which approved H2. H3 shows that self-regulated learning significantly and positively influences teacher credibility, which is also supported by ($\beta = 0.042$, $t = 2.085$, $p \leq 0.05$). Study findings support H1, H2, and H3, as shown in Table 6.

Mediation analysis

The study employed teachers' credibility and technological competencies to mediate the relationship between self-regulated learning and student academic performance. VAF technique was applied to measure mediation (71). Furthermore, the strength of this mediator was evaluated using the Variance Accounted for (VAF) method of estimating relative absorption suggested by Hair et al. (72). According to the VAF approach, VAF >80% show full mediation, 20%<VAF >80% show partial mediation, and less than 20% show no mediation. Nitzl et al. (73) added that particle mediation exists when there is a significant indirect and direct relationship between variables. The results illustrate that technological competencies partially mediate the relationship between self-regulated learning and student learning outcome as the direct effect ($\beta = 0.405$, $t = 2.784$, $p \leq 0.05$) and indirect effect ($\beta = 0.549$, $t = 6.455$, $p \leq 0.05$) with VAF 70.3% show partial mediation. We proposed the hypothesis that teachers' credibility mediates the relationship between self-regulated learning and medical students' performance. Again, the findings demonstrate that partial mediation of teachers' credibility between self-regulated learning and medical student learning outcomes as the direct effect ($\beta = 0.405$, $t = 2.784$, $p \leq 0.05$) and indirect effect ($\beta = 0.220$, $t = 6.760$, $p \leq 0.000$) with VAF 68%. The results support H4 and H5 as shown in Table 7.

Moderating analysis

The study further investigated the moderating influence of perceived institutional support to moderate the relationships between self-regulated learning, technological competencies, and teacher credibility. Table 8 shows that perceived institutional support

TABLE 7 Mediation analysis.

Relationship	Direct effect	Indirect effect	Total effect	VAF	Decision
Self-regulated learning->Technological competencies->Student learning outcome	$\beta = 0.405$, T-value = 2.784, P-value ≤0.05	$\beta = 0.549$, T-value = 6.455, P-value ≤0.05	$\beta = 0.743$, p-value = 0.000, T-value = 22.738	70.3%	Partial mediation
Self-regulated learning->Teachers credibility->Student learning outcome	$\beta = 0.405$, T-value = 2.784, p-value ≤0.05	$\beta = 0.220$, p-value ≤0.000, T-value = 6.760	$\beta = 0.584$, p-value = 0.000, T-value = 42.579	68%	Partial mediation

TABLE 8 Moderation analysis.

Hypothesis testing	β	T-value	p-value	Decision
SRL × PIS->TC	0.049	3.128	0.041	Supported
SRL × PIS->TC	0.017	2.765	0.032	Supported

moderates the relationship between self-regulated learning and teacher credibility with ($\beta = 0.049$ $t = 3.128$, $p \leq 0.05$). The study findings confirm that perceived institutional moderate the relation between self-regulated and technological credibility with ($\beta = 0.017$, $t = 2.765$, $p \leq 0.05$) support H8. Findings support H9.

Discussion

This study indicated that self-regulated learning significantly impacts student learning outcomes under the umbrella of blended learning. This finding relates to the idea that blended learning is comparable in effectiveness to traditional classroom-based learning (4). Su et al. (7) and Xu and Jaggars (74) also found that, on average, students who took online courses performed better academically than those who took conventional in-person courses. The research stressed the importance of course design and student peer support facilities in blended learning environments. This suggests the flexibility and convenience that online learning creates improve learning outcomes.

The study results further revealed that self-regulatory learning mediates the role of teachers' credibility and technological competencies. Moreover, the study found that perceived institutional support moderates the relationship between self-regulation, perceived teacher credibility, and technological competencies. This was aligned with the fact students do better when they trust their instructors (13, 52).

The study analyzed adaptations in teachers' levels of success concerning their credibility, competence, and kindness, and the findings indicated that teachers' competence is significant for students' academic achievement, followed by teachers' likability and credibility. The study found that technological competence mediates the relationship between self-regulated learning and student learning outcomes, as Anthonysamy et al. (24) indicated. Numerous studies have also shown a strong correlation between students' technological competence and learning outcomes in online courses (7). In line with this, the current study showed a favorable relationship between students' technological competence, engagement in blended learning, and overall learning outcomes. In addition, the findings revealed that students' technological competence was crucial in mediating the connection between their learning outcomes and blended courses. Students with good technological competence were able to engage more in blended classrooms and perform better in learning outcomes. This demonstrates that blended learning outcomes are positively correlated with students' levels of technological competence.

Furthermore, the study results show that the association between self-regulated learning and perceived institutional support is moderated by the perceived degree of teacher credibility; i.e., when perceived institutional support is high, teacher's credibility is high. Similarly, perceived institutional support positively correlated with student happiness and perceived learning outcomes. This highlights the value of perceived institutional support that might enhance learning when interacting with others online. Hill and Smith's (11) study also indicates the correlation between blended course completion rates and students' reports of perceived institutional support. Overall, students with perceived institutional support were expected to do well in blended courses and academic performance. This suggests that perceived institutional support significantly influences students' participation and persistence in online education. Regarding the relationship between teachers' credibility and student participation in blended learning, the study found that students' perceptions of the teacher's credibility are positively correlated with their course interest and satisfaction. This implies that students' faith in their online teachers might significantly affect their learning outcomes.

Conclusion

After the outbreak of COVID-19, there have been substantial changes in education, necessitating a swift shift to online instruction to maintain continuity in the face of the emergency. This trend was also found to be beneficial to higher education institutions as they can integrate both online and face-to-face teaching (17–19). Blended education is essential in improving students' academic performance, notably medical students. However, this study indicates that blended learning is influenced by various factors, such as teaching credibility and technological competence. Moreover, a friendly learning climate is critical for fostering motivation, engagement, and overall academic accomplishment in the virtual setting. Teachers' character, expertise, and resources might significantly affect students' learning motivation and academic achievement in classrooms.

The study further argues that self-regulatory learning is vital forblended learning as it mediates the role of teachers' credibility and technological competencies. This suggests that teachers' credibility

and technical capabilities are strongly associated with students' learning experiences across subjects in medical education. Teachers' technological competence also mediates the positive correlation between the blended learning environment and student academic performance and perceives teacher's credibility. These factors become crucial in determining students' active involvement and academic performance in blended courses. In addition, the study concluded that perceived institutional support is a significant mediator in the relationship between self-regulated learning and teachers' credibility and technology competencies.

This study contributes to designing friendly and effective blended learning methodologies and support systems for students in medical sciences and other disciplines. It also helps teachers and other stakeholders create a friendly virtual classroom, therefore raising students' academic performance. While the study's primary population is medical students, its findings may have broader applicability and assist students of all majors and settings. It can help educational institutions to create a positive and encouraging blended learning environment by placing a premium on teacher credibility, technological proficiency, and the promotion of perceived institutional support.

Limitation and future direction

This study provides insights into the factors that affect students' academic performance in a blended learning environment. However, it is essential to acknowledge certain limitations. First, the study used convenient sampling methods in collecting the data, which might create a sampling bias. Furthermore, the study primarily examined undergraduate medical students with self-report measures, which may have been affected by some degree of response bias. Hence, future research should consider incorporating a more diverse sample to enhance the findings and broaden their generalizability. Moreover, including objective measures, such as academic performance data or observation of online interactions, could improve the evidence's strength.

Future research could explore additional variables, such as student self-efficacy, parental involvement, and peer support, to further understand their impact on students' academic achievement in blended learning. Longitudinal studies offer valuable insights into these variables' enduring effects and dynamic interactions over an extended period. Additionally, it would be advantageous to investigate the efficacy of interventions or strategies to foster a positive blended learning environment and improve teacher proficiency.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethics Committee of Hunan University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MA: Conceptualization, Funding acquisition, Supervision, Writing – original draft. ST: Conceptualization, Investigation, Resources, Supervision, Writing – review & editing. NG: Formal analysis, Methodology, Software, Writing – original draft. MS: Formal analysis, Resources, Validation, Writing – review & editing. HD: Resources, Software, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Taneja M, Kiran R, Bose SC. Understanding the relevance of experiential learning for entrepreneurial self-efficacy: a gender-wise perspective. *Int J Manag Educ*. (2023) 21:100760. doi: 10.1016/j.ijme.2022.100760

2. Topping KJ, Douglas W, Robertson D, Ferguson N. Effectiveness of online and blended learning from schools: a systematic review. *Rev Educ*. (2022) 10:3353. doi: 10.1002/rev3.3353

3. Wu T-T, Lee H-Y, Li P-H, Huang C-N, Huang Y-M. Promoting self-regulation progress and knowledge construction in blended learning via ChatGPT-based learning aid. *J Educ Comput Res*. (2024) 61:3–31. doi: 10.1177/07356331231191125

4. Müller C, Mildenberger T, Steingruber D. Learning effectiveness of a flexible learning study programme in a blended learning design: why are some courses more effective than others? *Int J Educ Technol High Educ*. (2023) 20:379. doi: 10.1186/s41239-022-00379-x

5. Rafiola RH, Setyosari P, Radjah CL, Ramli M. The effect of learning motivation, self-efficacy, and blended learning on students' achievement in the industrial revolution 4.0. *Int J Emerg Technol Learn*. (2020) 15:71–82. doi: 10.3991/ijet.v15i08.12525

6. Alamri HA, Watson S, Watson W. Learning technology models that support personalization within blended Learning environments in higher education. *TechTrends*. (2020) 65:62–78. doi: 10.1007/s11528-020-00530-3

7. Su F, Zou D, Wang L, Kohnke L. Student engagement and teaching presence in blended learning and emergency remote teaching. *J Comput Educ*. (2023). doi: 10.1007/s40692-023-00263-1

8. Dziuban CD, Picciano AG. Education and blended Learning In: Graham CR, Moskal PD. (Eds.). Blended Learning. London: Routledge (2021). 365–402.

9. Anthonysamy L, Koo A-C, Hew S-H. Self-regulated learning strategies and non-academic outcomes in higher education blended learning environments: a one decade review. *Educ Inf Technol*. (2020) 25:3677–704. doi: 10.1007/s10639-020-10134-2

10. Xu Z, Zhao Y, Liew J, Zhou X, Kogut A. Synthesizing research evidence on self-regulated learning and academic achievement in online and blended learning environments: a scoping review. *Educ Res Rev*. (2023) 39:100510. doi: 10.1016/j.edurev.2023.100510

11. Hill J, Smith K. Visions of blended learning: identifying the challenges and opportunities in shaping institutional approaches to blended learning in higher education. *Technol Pedagog Educ*. (2023) 32:289–303. doi: 10.1080/1475939X.2023.2176916

12. Gómez CJ, Hinojo-Lucena FJ, Moreno-Vera JR, Alonso-Garcia S. Analysis of a forced blended-learning program in social sciences higher education during the COVID-19 post-pandemic. *Education+ Training*. (2023) 65:298–311. doi: 10.1108/ET-06-2022-0246

13. Setyosari P, Kuswandi D, Ulfa S. Creative problem solving process instructional design in the context of blended learning in higher education. *Electronic J E-Learn*. (2023) 21:80–97. doi: 10.34190/ejel.21.2.2653

14. Asarta CJ, Schmidt JR. The effects of online and blended experience on outcomes in a blended learning environment. *Internet High Educ*. (2020) 44:100708. doi: 10.1016/j.iheduc.2019.100708

15. Versteijlen M, Wals AEJ. Developing design principles for sustainability-oriented blended Learning in higher education. *Sustain For*. (2023) 15:8150. doi: 10.3390/su15108150

16. Kuo T-H, Tien H-K. Enhancing the effects of creativity training for business school students through art-based methods and blended learning. *Education + Training*. (2022) 64:642–61. doi: 10.1108/et-07-2021-0282

17. Ashraf MA, Shabnam N, Tsegay SM, Huang G. Acceptance of smart technologies in blended learning: perspectives of chinese medical students. *Int J Environ Res Public Health*. (2023) 20:2756. doi: 10.3390/ijerph20032756

18. Ashraf MA, Tsegay SM, Meijia Y. Blended learning for diverse classrooms: qualitative experimental study with in-service teachers. *SAGE Open*. (2021) 11:21582440211030623. doi: 10.1177/21582440211030623

19. Tsegay SM, Ashraf MA, Perveen S, Zegergish MZ. Online teaching during COVID-19 pandemic: teachers' experiences from a Chinese university. *Sustain For*. (2022) 14:568. doi: 10.3390/su14010568

20. Sumardjo M, Supriadi YN. Perceived organizational commitment mediates the effect of perceived organizational support and organizational culture on organizational citizenship behavior. *CAL*. (2023) 24:376–84. doi: 10.47750/QAS/24.192.45

21. Zheng W, Ma Y-Y, Lin H-L. Research on blended Learning in physical education during the COVID-19 pandemic: a case study of Chinese students. *SAGE Open*. (2021) 11:215824402110581. doi: 10.1177/21582440211058196

22. Masnadi NN. The development of a Metaverse app for a blended Learning in higher education institutions In: Metaverse applications for new business models and disruptive innovation. New York: IGI Global (2023). 82–101.

23. Bandura A. Social learning theory. Englewood Cliffs, NJ: Prentice Hall (1977). 247 p.

24. Anthonysamy L, Koo AC, Hew SH. Self-regulated learning strategies in higher education: fostering digital literacy for sustainable lifelong learning. *Educ Inf Technol*. (2020) 25:2393–414. doi: 10.1007/s10639-020-10201-8

25. Dilshad MN. Learning theories: Behaviorism, cognitivism, constructivism. *Int Educ Res J*. (2017) 3:64–6.

26. Yusra A, Neviyarni S, Erianjoni E. A review of Behaviorist Learning theory and its impact on the Learning process in schools. *Int J Educ Dyn*. (2022) 5:81–91. doi: 10.24036/ijeds.v5i1.373

27. Rosli MS, Saleh NS, Md Ali A, Abu Bakar S. Self-determination theory and online Learning in university: advancements. *Sustain For*. (2022) 14:14655. doi: 10.3390/su142114655

28. Bouilheres F, Le LTVH, McDonald S, Nkhoma C, Jandug-Montera L. Defining student learning experience through blended learning. *Educ Inf Technol*. (2020) 25:3049–69. doi: 10.1007/s10639-020-10100-y

29. Cho M-H, Heron ML. Self-regulated learning: the role of motivation, emotion, and use of learning strategies in students' learning experiences in a self-paced online mathematics course. *Distance Educ*. (2015) 36:80–99. doi: 10.1080/01587919.2015.1019963

30. Hong J-C, Lee Y-F, Ye J-H. Procrastination predicts online self-regulated learning and online learning ineffectiveness during the coronavirus lockdown. *Personal Individ Differ*. (2021) 174:110673. doi: 10.1016/j.paid.2021.110673

31. Xu Z, Zhao Y, Zhang B, Liew J, Kogut A. A meta-analysis of the efficacy of self-regulated learning interventions on academic achievement in online and blended environments in K-12 and higher education. *Behav Inform Technol*. (2023) 42:2911–31. doi: 10.1080/0144929X.2022.2151935

32. Rasheed RA, Kamsin A, Abdullah NA. Challenges in the online component of blended learning: a systematic review. *Comput Educ*. (2020) 144:103701. doi: 10.1016/j.compedu.2019.103701

33. Li S, Wang W. Effect of blended learning on student performance in K-12 settings: a meta-analysis. *J Comput Assist Learn*. (2022) 38:1254–72. doi: 10.1111/jcal.12696

34. Yang H, Cai J, Yang HH, Wang X. Examining key factors of beginner's continuance intention in blended learning in higher education. *J Comput High Educ*. (2022) 35:126–43. doi: 10.1007/s12528-022-09322-5

35. Liu K, Zhang W, Li W, Wang T, Zheng Y. Effectiveness of virtual reality in nursing education: a systematic review and meta-analysis. *BMC Med Educ*. (2023) 23:710. doi: 10.1186/s12909-023-04662-x

36. Liu Q, Du X, Lu H. Teacher support and learning engagement of EFL learners: the mediating role of self-efficacy and achievement goal orientation. *Curr Psychol*. (2022) 42:2619–35. doi: 10.1007/s12144-022-04043-5

37. Costello E, Welsh S, Girme P, Concannon F, Farrelly T, Thompson C. Who cares about learning design? Near future superheroes and villains of an educational ethics of care. *Learn Media Technol*. (2023) 48:460–75. doi: 10.1080/17439884.2022.2074452

38. Reinecke L, Meier A, Beutel ME, Schemer C, Stark B, Wölfling K, et al. The relationship between trait procrastination, internet use, and psychological functioning: results from a community sample of German adolescents. *Front Psychol*. (2018) 9:913. doi: 10.3389/fpsyg.2018.00913

39. Zheng J, Wu G. Work-family conflict, perceived organizational support and professional commitment: a mediation mechanism for Chinese project professionals. *Int J Environ Res Public Health*. (2018) 15:344. doi: 10.3390/ijerph15020344

40. Bernarto I., Bachtiar D., Sudibjo N., Suryawan I. N., Purwanto A., Asbari M. (2020). Effect of transformational leadership, perceived organizational support, job satisfaction toward life satisfaction: Evidences from indonesian teachers. *Int. J. Adv. Sci. Res*. 29:5495–5503.

41. Jehanzeb K. Does perceived organizational support and employee development influence organizational citizenship behavior? Person–organization fit as moderator. *European J Train Dev*. (2020) 44:637–57. doi: 10.1108/EJTD-02-2020-0032

42. Lee SJ, Kim TH, Kim SO. Impact of Core competencies of technological innovation Startups on financial performance through innovation activities. *J Pract Eng Educ*. (2024) 16:433–47. doi: 10.14702/JPEE.2024.433

43. Bamoallem B, Altarteer S. Remote emergency learning during COVID-19 and its impact on university students perception of blended learning in KSA. *Educ Inf Technol*. (2022) 27:157–79. doi: 10.1007/s10639-021-10660-7

44. Kalkan Ü, Altınay Aksal F, Altınay Gazi Z, Atasoy R, Dağlı G. The relationship between school administrators' leadership styles, school culture, and organizational image. *SAGE Open*. (2020) 10:2158244020902081. doi: 10.1177/2158244020902081

45. Finn AN, Schrodt P, Witt PL, Elledge N, Jernberg KA, Larson LM. A meta-analytical review of teacher credibility and its associations with teacher Behaviors and student outcomes. *Commun Educ*. (2009) 58:516–37. doi: 10.1080/03634520903131154

46. Bruggeman B, Tondeur J, Struyven K, Pynoo B, Garone A, Vanslambrouck S. Experts speaking: crucial teacher attributes for implementing blended learning in higher education. *Internet High Educ*. (2021) 48:100772. doi: 10.1016/j.iheduc.2020.100772

47. Pishghadam R, Derakhshan A, Zhaleh K, Al-Obaydi LH. Students' willingness to attend EFL classes with respect to teachers' credibility, stroke, and success: a cross-cultural study of Iranian and Iraqi students' perceptions. *Curr Psychol*. (2023) 42:4065–79. doi: 10.1007/s12144-021-01738-z

48. Philipsen B, Tondeur J, Blieck Y, Vanslambrouck S. Teacher professional development for online teaching: an update of insights stemming from contemporary research In: Learning, design and technology: An international compendium of theory, research, practice, and policy. Cham: Springer International Publishing (2023). 527–54.

49. Bryman A. Of methods and methodology. *Qual. Res. Organ. Manag.* (2008) 3:159–68. doi: 10.1108/17465640810900568

50. Al-Omoush KS, Simón-Moya V, Sendra-García J. The impact of social capital and collaborative knowledge creation on e-business proactiveness and organizational agility in responding to the COVID-19 crisis. *J Innov Knowl*. (2020) 5:279–88. doi: 10.1016/j.jik.2020.10.002

51. Javier C. The shift towards new teaching modality: examining the attitude and technological competence among language teachers teaching Filipino. *Asian ESP*. (2020) 16:210–44.

52. Li-I Hsu L. The relationship between English teacher Misbehaviors in the classroom and students' perception of teacher credibility. *Int J English Lang Educ*. (2014) 2:11. doi: 10.5296/ijele.v2i2.5548

53. Teven JJ, McCroskey JC. The relationship of perceived teacher caring with student learning and teacher evaluation. *Commun Educ*. (1997) 46:1–9. doi: 10.1080/03634529709379069

54. San CK, Guo H. Institutional support, social support, and academic performance: mediating role of academic adaptation. *Eur J Psychol Educ*. (2023) 38:1659–75. doi: 10.1007/s10212-022-00657-2

55. la Fuente J, Zapata L, Martínez-Vicente JM, Cardelle-Elawar M, Sander P, Justicia F, et al. Regulatory teaching and self-regulated Learning in college students: confirmatory validation study of the IATLP scales. *Electronic J Res Educ Psychol*. (2017) 10:839–66. doi: 10.25115/ejrep.v10i27.1511

56. Avotra AARN, Chenyun Y, Yongmin W, Lijuan Z, Nawaz A. Conceptualizing the state of the art of corporate social responsibility (CSR) in green construction and its

nexus to sustainable development. *Front Environ Sci*. (2021) 9:541. doi: 10.3389/fenvs.2021.774822

57. Valdez-Juárez LE, Castillo-Vergara M, Ramos-Escobar EA. Innovative business strategies in the face of COVID-19: an approach to open innovation of SMEs in the Sonora region of Mexico. *J Open Innov: Technol Mark Complex*. (2022) 8:47. doi: 10.3390/joitmc8010047

58. Cepeda-Carrion I, Ortega-Gutierrez J, Garrido-Moreno A, Cegarra-Navarro JG. The mediating role of knowledge creation processes in the relationship between social media and open innovation. *J Knowl Econ*. (2022) 14:1275–97. doi: 10.1007/s13132-022-00949-4

59. Gull N, Song Z, Shi R, Asghar M, Rafique MA, Liu Y. Paternalistic leadership, Polychronicity, and life satisfaction of nurses: the role of work-family conflict and family-work conflict in public sector hospitals. *Front Psychol*. (2021) 12:3474. doi: 10.3389/fpsyg.2021.648332

60. Kern BD, Ellison DW, Killian CM, Widmer F. Initial validation of the teaching sustainability questionnaire and relationships of latent factors predicting physical education teachers intent to remain working in high poverty schools. *Meas Phys Educ Exerc Sci*. (2020) 24:181–93. doi: 10.1080/1091367X.2020.1760870

61. Hair Joe FJ, Sarstedt M, Matthews LM, Ringle CM. Identifying and treating unobserved heterogeneity with FIMIX-PLS: part I–method. *Eur Bus Rev*. (2016) 28:63–76. doi: 10.1108/EBR-09-2015-0094

62. Fornell C, Larcker DF. Structural equation models with unobservable variables and measurement error: Algebra and statistics. Los Angeles, CA: Sage Publications Sage CA (1981).

63. Henseler J, Ringle CM, Sarstedt M. A new criterion for assessing discriminant validity in variance-based structural equation modeling. *J Acad Mark Sci*. (2015) 43:115–35. doi: 10.1007/s11747-014-0403-8

64. Hair JFJr, Hult GTM, Ringle CM, Sarstedt M, Danks NP, Ray S. Partial least squares structural equation modeling (PLS-SEM) using R: A workbook. Berlin: Springer Nature (2021).

65. Hair JF, Hult GTM, Ringle CM, Sarstedt M, Danks NP, Ray S. Mediation analysis In: Partial least squares structural equation Modeling (PLS-SEM) using R. Cham: Springer (2021). 139–53.

66. Hair JFJr, M Hult GT, M Ringle C, Sarstedt M, Castillo Apraiz J, Cepeda Carrión GA, et al. Manual de Partial Least Squares Structural Equation Modeling (PLS-SEM) (Segunda Edición). *OmniaScience*. (2019). doi: 10.3926/oss.37

67. Asghar M, Gull N, Tayyab M, Zhijie S, Tao X. Polychronicity at work: work engagement as a mediator of the relationships between job outcomes. *J Hosp Tour Manag*. (2020) 45:470–8. doi: 10.1016/j.jhtm.2020.10.002

68. Asghar M, Tayyab M, Gull N, Zhijie S, Shi R, Tao X. Polychronicity, work engagement, and turnover intention: the moderating role of perceived organizational support in the hotel industry. *J Hosp Tour Manag*. (2021) 49:129–39. doi: 10.1016/j.jhtm.2021.09.004

69. Khan GF, Sarstedt M, Shiau W-L, Hair JF, Ringle CM, Fritze MP. Methodological research on partial least squares structural equation modeling (PLS-SEM): an analysis based on social network approaches. *Internet Res*. (2019) 29:407–29. doi: 10.1108/IntR-12-2017-0509

70. Hair JFJr, Matthews LM, Matthews RL, Sarstedt M. PLS-SEM or CB-SEM: updated guidelines on which method to use. *Int J Multivar Data Anal*. (2017) 1:107–23. doi: 10.1504/IJMDA.2017.087624

71. Bari BA, Grossman CD, Lubin EE, Rajagopalan AE, Cressy JI, Cohen JY. Stable representations of decision variables for flexible behavior. *Neuron*. (2019) 103:922–933.e7. doi: 10.1016/j.neuron.2019.06.001

72. Hair JF, Ringle CM, Sarstedt M. Partial least squares structural equation modeling: rigorous applications, better results and higher acceptance. *Long Range Plan*. (2013) 46:1–12. doi: 10.1016/j.lrp.2013.01.001

73. Nitzl C, Sicilia M, Steccolini I. Exploring the links between different performance information uses, NPM cultural orientation, and organizational performance in the public sector. *Public Manag Rev*. (2019) 21:686–710. doi: 10.1080/14719037.2018.1508609

74. Xu D, Jaggars SS. The impact of online learning on students' course outcomes: evidence from a large community and technical college system. *Econ Educ Rev*. (2013) 37:46–57. doi: 10.1016/j.econedurev.2013.08.001

Frontiers in Medicine

Translating medical research and innovation into improved patient care

A multidisciplinary journal which advances our medical knowledge. It supports the translation of scientific advances into new therapies and diagnostic tools that will improve patient care.

Discover the latest Research Topics

See more →

Frontiers

Avenue du Tribunal-Fédéral 34
1005 Lausanne, Switzerland
frontiersin.org

Contact us

+41 (0)21 510 17 00
frontiersin.org/about/contact