BMC Medical Education

RESEARCH

Open Access

The evolution of medical education in the era of Covid-19 and beyond: a longitudinal study

Yinan Zhao[1,2†], Tianyi Sun[3†], Xinyue Zhang[4], Xinyi Wang[5] and Wenyu Hu[6*]

Abstract

Background The COVID-19 pandemic has brought about profound transformations in nearly all aspects of life, leaving its impact on the global community as a whole. Nowhere has this transformation been more pronounced than in the sphere of education, including medical education. Healthcare professionals and educators faced the daunting task of preparing the next generation of practicing physicians amid the ongoing public health crisis.

Methods The study involved students from three different Chinese medical universities (groups A, B, and C, respectively). The research employed two instruments: a Scale of Satisfaction with Simulation-Based Education and a Scale of Satisfaction with Telemedicine Competency Education. Data were collected at three different time points: 2020–2021 (online/distance learning), 2021–2022 (hybrid learning), and 2022–2023 (traditional face-to-face learning).

Results It was revealed that students demonstrated the highest level of satisfaction during the hybrid learning period (Time Point 2), while online/distance learning (Time Point 1) received the lowest ratings. Statistical analysis indicated significant differences in satisfaction levels across the various time points.

Conclusions Hybrid learning emerged as the preferred method among students, yielding the highest level of satisfaction. Online/distance learning during the 2020–2021 academic year and traditional face-to-face instruction in 2022–2023 exhibited lower satisfaction levels. The research findings underscore the practical significance of hybrid learning for students in medical educational programs, suggesting its potential for optimizing educational curricula and resources within academic institutions.

Keywords Education, Medical education, Pandemic, Distance learning, Information technology, University

Background

The COVID-19 (Coronavirus Disease 2019) pandemic has brought about profound transformations in nearly all aspects of life, leaving its impact on the global community as a whole. Nowhere has this transformation been more pronounced than in the sphere of education, including medical education [1]. In a world where traditional norms and daily routines were disrupted, healthcare professionals and educators faced the daunting task of preparing the next generation of practicing physicians amid the ongoing public health crisis [2].

As the pandemic continued to evolve, a novel model of medical education emerged, driven by necessity,

†Yinan Zhao and Tianyi Su contributed equally to this manuscript.

*Correspondence:
Wenyu Hu
wenyuhu@gmx.com
[1]Department of Neurology, Xuanwu Hospital, National Center for Neurological Disorders, Capital Medical University, Beijing, China
[2]Department of Neurology, The First Hospital of China Medical University, Shenyang, China
[3]Youth League Committee, The First Hospital of China Medical University, Shenyang, China
[4]Department of Anesthesiology, The First Hospital of China Medical University, Shenyang, China
[5]Department of Academic Affairs, The First Hospital of China Medical University, Shenyang, China
[6]Department of Cardiology, The First Hospital of China Medical University, Shenyang, China

innovation, and the utilization of technology, before delving deeper into the transformation catalyzed by the COVID-19 pandemic [3]. It is crucial, however, to understand the traditional approach to medical education, as medical training, often considered one of the most rigorous and structured educational programs, has been built upon personal hands-on experience [4]. The traditional model focused on in-person learning, highlighting the importance of bedside manners, personal interaction, and practical skills vital for medical practice. While modern medical education incorporates certain digital tools and resources, in-person learning remains its cornerstone [5].

The COVID-19 pandemic wave presented an unprecedented challenge to medical education, as the traditional in-person learning model became unfeasible amidst quarantine measures and social distancing protocols [6]. Medical educational institutions were compelled to swiftly adapt to ensure the safety of students, faculty, and patients. The necessity to mitigate the virus's spread while maintaining the continuity of medical education led to the rapid evolution of teaching methods [7]. Distance learning and online education emerged as immediate solutions, with lectures that were once conducted in physical classrooms transitioning to virtual platforms [8]. Clinical rotations and hands-on experience were temporarily suspended and replaced by virtual patient encounters and simulation-based learning [9]. The pandemic accelerated the adoption of technology and distance learning in medical educational institutions, prompting innovations that were previously unimaginable [10–12].

As the world emerges from the grip of the pandemic, medical education stands at a crossroads. The lessons drawn from the crisis have ushered in a revolution in the training of future physicians, and medical education in the post-pandemic era is no longer rigidly defined by adherence to tradition. Instead, it incorporates a hybrid approach, utilizing both in-person and distance learning. Medical educational institutions now have the opportunity to blend the advantages of in-person instruction with the flexibility of digital resources. This article holds contemporary relevance as it delves into the profound impact of the COVID-19 pandemic on medical education, a critical component of healthcare system development. Its practical significance lies in providing educators, institutions, and policymakers with insights into successful adaptation to distance learning and the integration of new technologies into medical education. From a scholarly perspective, this contributes to the growing body of knowledge on innovative approaches to medical education, which are essential for shaping healthcare in a post-pandemic world.

Literature review

The COVID-19 pandemic has presented unprecedented challenges for medical education, necessitating the rapid adaptation of teaching methods, curricula, and technologies [13]. One of the most significant transformations has been the shift from traditional in-person instruction to virtual learning [14]. Existing research highlights the rapid transition to digital platforms and their impact, emphasizing the need for both educators and students to adapt in order to maintain an engaging and effective educational experience [8, 15]. Importantly, the flexibility in implementing online learning is emphasized, reiterating the practical challenges faced by educators and students during the pandemic [16].

Virtual learning in medical education offers both advantages and limitations. In the study [17], it is discussed how digital platforms can facilitate collaborative learning and provide students with greater autonomy in their education, while also potentially complicating the learning process. In 2020, scholars emphasized the critical importance of assessing the extent to which new approaches achieve their intended goals and identifying the factors that promote or hinder effective online learning. This assessment is crucial for implementing the most suitable systems once the pandemic subsides [17].

The integration of simulation and technology into medical education has gained prominence following the pandemic. Simulation-based learning allows students to practice clinical skills and make decisions in a controlled environment [18]. The study [19] discusses the increased interest in virtual patient encounters and the use of augmented and virtual reality to provide realistic clinical experiences for students. These tools can be valuable in bridging the gap between traditional hands-on training and distance learning, offering learners the opportunity to develop essential skills in a safe and controlled setting [19, 20]. Similarly, other studies underscore the effectiveness of simulation-based learning in medical education, highlighting its ability to enhance procedural skills, diagnostic reasoning, and teamwork [21, 22].

The pandemic accelerated the adoption of various educational technologies, which continue to be relevant in post-pandemic medical education by preparing students for real clinical settings [23]. Among these technologies, telemedicine has gained significant importance for both patient care and medical education [24]. It presents unique challenges and opportunities, such as enabling remote diagnosis and patient management, which are increasingly essential in modern healthcare [25]. As telemedicine becomes a fundamental component of healthcare, medical education must adapt to this evolving landscape. This adaptation is crucial not only for training future physicians but also reflects the broader evolution of the healthcare system in the post-pandemic era [26].

Distance learning in medical education presents both challenges and opportunities [8]. On one hand, it facilitated educational continuity during the crisis, allowing students to access lectures from the comfort of their homes, ensuring an uninterrupted flow of knowledge. Virtual platforms fostered collaborative learning, transcended geographical barriers, and enabled students to interact with peers and instructors [27]. However, it also raised critical questions, such as whether the essence of medical education, rooted in direct patient interactions and clinical skills, can be effectively conveyed through digital platforms. Additionally, it poses challenges in how educators will ensure that students acquire the necessary practical experience and interpersonal skills that are integral to the medical profession [28]. Medical universities have begun exploring novel methods for simulating clinical experience, offering virtual patient interactions, and utilizing augmented and virtual reality for practical training [29]. While these technologies have not entirely replaced in-person clinical exposure, they have provided a viable temporary solution. They allow students to practice critical skills, enhance diagnostic thinking, develop efficient learning approaches, and practice patient communication in a virtual environment [15].

Maintaining a balance between in-person and online learning, ensuring the acquisition of essential clinical skills, and adapting to the evolving healthcare landscape remain persistent challenges [30]. The available literature highlights the ever-evolving character of medical education amid and following the COVID-19 pandemic. Despite apparent challenges, opportunities are also evident. The use of distance/online learning, simulation, and telemedicine education represents significant strides in shaping the future of medical education and holds scientific interest for further investigation. The current study addresses several significant gaps in the existing literature on student satisfaction with various teaching methods during the pandemic. This longitudinal research design allows for a more nuanced reflection of the dynamic nature of the pandemic and its impact on students' perceptions of different teaching methods. Unlike cross-sectional studies that collect data at a single point in time, this research analyzes student satisfaction at three distinct time points, providing a more comprehensive understanding of changes and adaptations in teaching. Special attention is given to the characteristics of the studied population, comprising students from three different Chinese medical universities, which helps to account for cultural and institutional differences in the perception of teaching methods. Additionally, the study emphasizes the integration of simulation-based learning (SBL) and telemedicine, highlighting the importance of these methods in enhancing student engagement and improving their educational experience in both virtual and in-person learning environments.

Research objectives

This article presents the findings of a longitudinal study involving 240 medical students, which can offer valuable insights into the adaptation and evolution of medical education during the COVID-19 era and the post-pandemic period. This is explained by the fact that it examines student satisfaction with various teaching methods during the pandemic, and the data obtained can assist educational institutions in identifying the most effective methods and adapting their programs to improve the quality of education. The study aims to deepen the understanding of how medical students perceive different forms of education. It covers fully online/distance learning during the 2020–2021 academic year, hybrid learning during the 2021–2022 academic year, and traditional in-person learning during the 2022–2023 academic year. Specifically, it investigates how these forms of education impacted students' satisfaction with simulation-based learning and the development of telemedicine competencies. The research entailed the following investigative objectives:

1. To determine the satisfaction levels of medical students with simulation-based learning at three different time points, contingent on the mode of instruction in each academic year, and to check for statistically significant differences in the indicators.
2. To ascertain the satisfaction levels of medical students with telemedicine competence education at three different time points, contingent on the mode of instruction in each academic year, and to check for statistically significant differences in the indicators.

Methods

Study design

This study employs a longitudinal design, encompassing three measurement time points: May 2021 (online/distance learning), May 2022 (hybrid learning), and May 2023 (in-person learning). The study involved students from three Chinese medical universities (Groups A, B, and C, respectively). Every year since the beginning of the pandemic, students from three Chinese universities have started practicing simulation-based learning and acquiring telemedicine competencies. These two programs were introduced in response to the pandemic and its impact, as well as the new challenges that emerged for the teachers, students, and university administration. On average, the expected frequency and duration of various interventions were identical: all types of sessions (online/distance, hybrid, and traditional in-person) were

conducted three times per week, with each session lasting 1.5 h.

In Fig. 1, a program is depicted that was utilized for instructional purposes based on simulation in medical education across three distinct modes of instruction: online distance learning, hybrid learning, and traditional face-to-face learning. This program considered the unique characteristics and strengths of each mode, providing flexibility and adaptability to various learning conditions while concurrently maximizing the advantages of simulation-based learning in medical education. Figure 2 presents a schematic representation of competency acquisition and development in the field of telemedicine, applicable to online/distance learning, hybrid learning, and traditional face-to-face learning. This program also recognized the necessity for adaptability and proposed measures and methods tailored to each mode of instruction, ensuring that learners can effectively acquire and cultivate telemedicine skills.

Simulation-based medical education entailed an instructional approach that involved the use of simulation to replicate real clinical scenarios, patient interactions, and medical procedures, enabling medical students to practice and refine their clinical skills and make decisions in a controlled and safe environment without putting real patients at risk. Various tools were utilized,

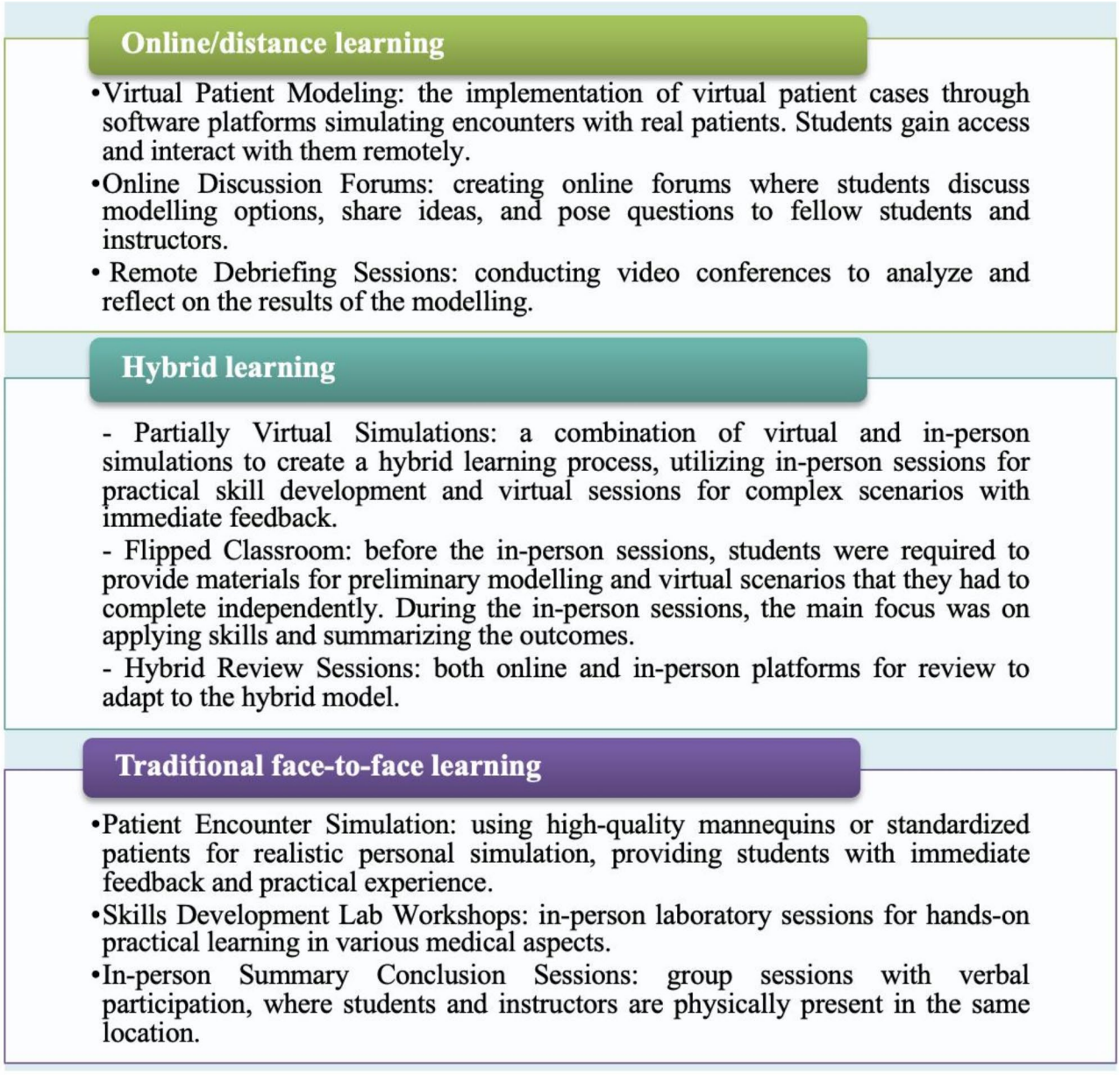

Fig. 1 Features of simulation-based learning in medical education across three different learning modes

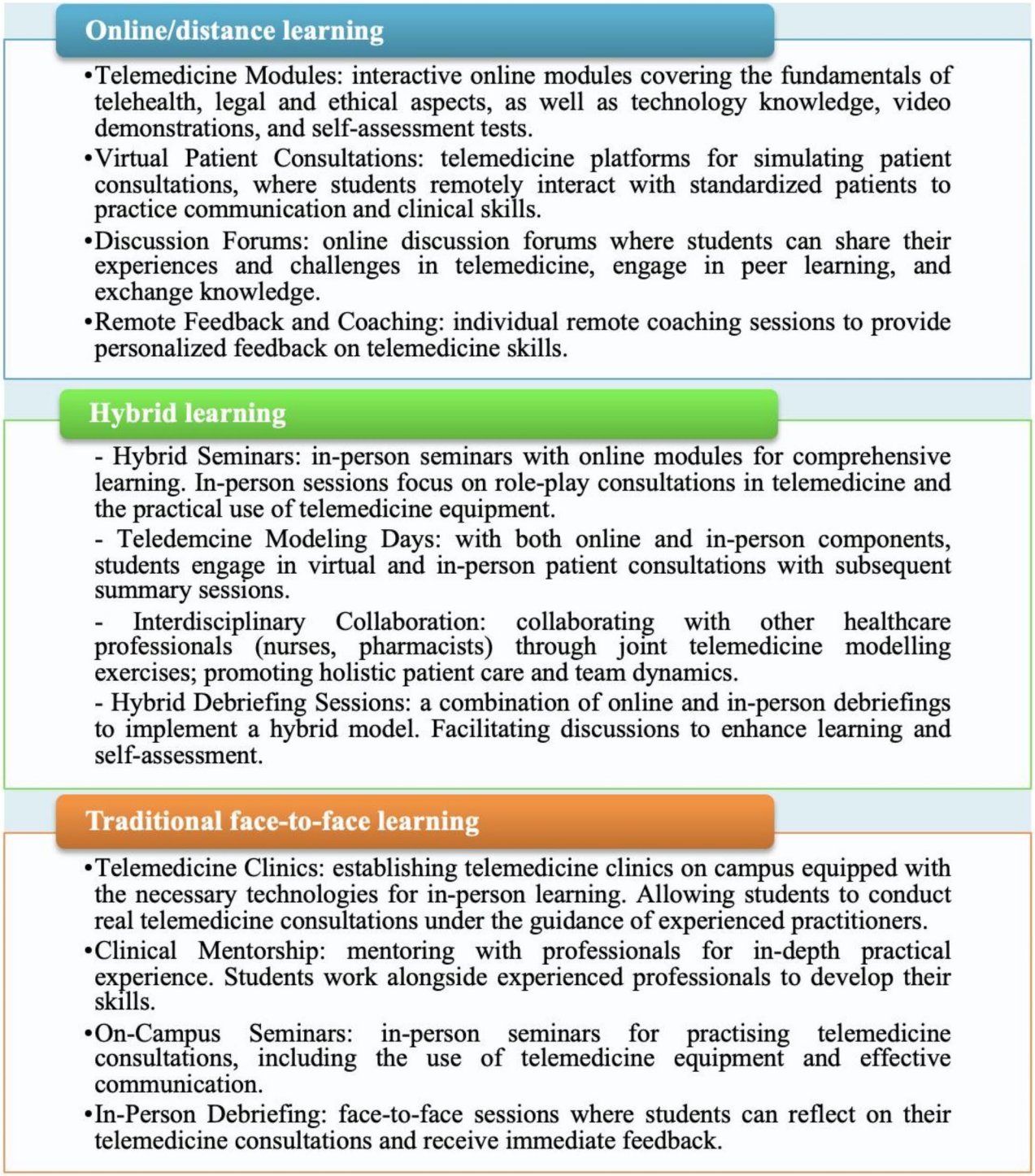

Fig. 2 Features of competency acquisition and development in the field of telemedicine in three different modes of instruction

including high-fidelity mannequins and models that simulate human anatomy, standardized patients, ultrasound simulators, and scenarios for team-based exercises. On the other hand, telemedicine implies a healthcare delivery system that utilizes telecommunication technologies for the remote provision of clinical services. Various communication tools were employed in the education process, such as video calls, telephone conversations, secure messaging exchanges, and remote monitoring devices. The study spanned three academic years, from September 2020 to May 2023, a period during which the pandemic was essentially recognized as concluded.

At the end of each of the three academic years, respondents completed two specially developed scales using online forms, with the data securely stored on a protected server. Each year, students studied telecommunication and modulation through different subjects and under varying circumstances. Importantly, the method of instruction changed each year. In addition to the respondents themselves, the study involved 38 teachers from three different universities and 10 psychologists who supervised and were available to students for support or assistance when needed.

Participants

The study involved third-year medical students from Chinese universities, who participated voluntarily. Invitations were sent to their email addresses, and participation was confirmed by 80 students from each university, totaling 240 students. A minimum of 80 students per university was established to ensure an even distribution of participants across the three universities and to maintain a manageable sample size for analysis. The response rate among students who participated in the study was 60%, providing insight into the representativeness of the included population. All students who consented to participate were included in the study, confirming a high level of voluntary engagement. The same sample of students was used at each time point, meaning that the same participants completed the survey over the course of all three years.

Scale

Specifically for this research, the development process of two scales commenced before its initiation. The first scale was the Simulation-Based Learning Satisfaction Scale, while the second was the Telemedicine Competence Education Satisfaction Scale. Each scale comprised 20 statements, and participants could express their agreement with each statement using a 5-point Likert scale, ranging from 1 (completely disagree) to 5 (completely agree). After collecting responses, it was necessary to calculate the mean scores for each statement and overall satisfaction by averaging the scores.

Before the development process, a comprehensive literature review was conducted to understand existing research in the current field. Subsequently, a set of potential statements related to satisfaction in the chosen variables was created. Next, an online approach was used to involve a panel of experts, including educators, healthcare professionals, and a psychologist, to assess the initial items for content validity. Two initial versions of the two scales were administered to thirty respondents to evaluate the clarity and comprehensibility of the items, resulting in some revisions based on respondent feedback. The assessment of validity involved three key aspects: firstly, content validity, in which experts reviewed the scale to confirm that it comprehensively covered the relevant domain; secondly, construct validity, focusing on factor analysis to determine whether the items aligned with the expected factors; and thirdly, an evaluation of convergent and discriminant validity, investigating whether the scales exhibited the anticipated correlations with similar constructs (convergent validity) while also demonstrating the absence of correlations with unrelated constructs (discriminant validity). Internal consistency was assessed using Cronbach's alpha to determine if the scale items were consistent when measuring the same construct, and the values ranged from 0.847 to 0.903, indicating a high level of internal consistency. Additionally, factor analysis and correlation analyses were applied. Factor analysis was employed to determine whether the scale items corresponded to the expected factors and to identify underlying structures within the data. Correlational analysis was used to assess the relationships between variables and to examine the similarity of the scales to analogous constructs (convergent validity). All these procedures facilitated the development of two scales and prepared them for the research launch, scheduled for September 2020.

To analyze medical students' satisfaction with various teaching methods, the study encompassed three-time points. The first time point corresponds to the 2020–2021 academic year, during which instruction was conducted in an online/distance learning format. The second time point covers the 2021–2022 academic year, when hybrid learning, combining online and in-person instruction, was implemented. The third time point represents the 2022–2023 academic year when instruction reverted to the traditional in-person format. These time points facilitated the comparison of student satisfaction levels across different teaching modes and identified the most effective methods.

Data analysis

The obtained results were analyzed using the SPSS software package. To assess student satisfaction with various teaching methods (for simulation-based learning and telemedicine competencies), means, standard deviations, and medians were calculated for each group at each time point. The non-parametric Friedman test was applied to check for statistically significant differences in satisfaction levels across the three time points (online/distance learning, hybrid learning, and traditional in-person learning). The statistical analysis involved summing and comparing the overall satisfaction scores of participants across these two scales. The analysis was conducted separately for each student group from each university (Groups A, B, and C) at each time point. This approach allowed for the assessment of differences in satisfaction

Table 1 Participant information in the current study

Medical University	Total	Females	Males	Mean Age	SD
China Medical University (group A)	80	45	35	20.24	0.44
Shenyang Medical College (group B)	80	39	41	20.36	0.61
Dalian Medical University (group C)	80	43	37	20.17	0.57

levels based on the mode of education for each individual group.

Ethical issues

The researchers obtained ethical approval from the ethics boards of all three participating educational institutions, and all participants had the option to withdraw from the study if they wished; participation was voluntary. Additionally, written consent was obtained from all participants.

Results

The study involved 240 third-year medical students. They came from three universities in China. By the end of the study, these students had completed their fifth year. Table 1 provides detailed information about the number of participants from each university.

Thus, among the respondents, 52.92% were females, and 47.08% were males, with an average age of 20.26 at the beginning of the study and a standard deviation of 0.54. All of them were Chinese students enrolled in their first and second years at their respective universities without changing their institutions. According to the university order listed in the table, they were assigned specific groups: A, B, and C, respectively. All three universities adhere to the common standards and requirements established by the Ministry of Education of China, ensuring the comparability of data and results. However, there may be minor differences in teaching methods and emphases, which were considered when grouping students for analysis. Participants in the study were third- to fifth-year medical students. In the Chinese medical education system, third-year students are transitioning from preclinical to clinical training. Fourth- and fifth-year students are already actively engaged in clinical activities and practice, making their experiences and perceptions of different teaching methods particularly valuable for this study. Prior to the COVID-19 pandemic, most students and faculty had limited experience with virtual or hybrid learning. The shift to these modes of instruction became a necessary adaptation to new conditions, further underscoring the relevance and importance of the study for understanding the impact of these methods on student satisfaction and perceptions.

The first objective of the study was to determine the satisfaction of medical students at each of the three universities with their simulation-based education at three different time points, depending on the mode of instruction in each academic year. The results are presented in Table 2.

For Group A, students from the first participating university, the median satisfaction score at Time Point 1, when they engaged in online/distance learning, was 49.50 [46.00, 51.00], at Time Point 2, during hybrid learning, the median score increased to 62.00 [60.00, 65.00], and at Time Point 3, after transitioning to traditional face-to-face learning, the median score was 56.00 [52.00, 58.00]. For Group B, the respective median scores were 51.00 [49.00, 52.00] during online/distance learning, 63.50 [61.00, 66.00] during hybrid learning, and 53.00 [51.00, 55.00] during traditional face-to-face learning. Group C had slightly different results, with median scores of 50.50 [48.00, 54.00] at Time Point 1 (online/distance learning), 65.00 [63.00, 69.00] at Time Point 2 (hybrid learning), and 61.00 [57.00, 62.00] at Time Point 3 (traditional face-to-face learning). For all three groups, the hybrid learning phase (Time Point 2) consistently showed the highest level of satisfaction, while the online/distance learning phase (Time Point 1) had the lowest satisfaction scores. The non-parametric Friedman test was used to check for statistically significant differences in satisfaction levels across the three-time points. The *p*-values for all groups were below the 0.001 threshold, confirming that the differences in satisfaction levels across the three-time points were statistically significant, with hybrid learning being the most accepted mode of instruction.

The second objective of the study was to determine the satisfaction of medical students with the acquisition of telemedicine competency at three different time points, depending on the mode of instruction in each academic year. The data are presented in Table 3.

For Group A, students from the first participating university, the median satisfaction scores for telemedicine competency education at Time Point 1, when they engaged in online/distance learning, were 58.00 [55.00,

Table 2 Level of satisfaction with simulation-based learning by time points for each group, indicating medians, interquartile ranges, and *p*-values

Group	Online/Distance Learning (Mdn [Q1, Q3])	Hybrid Learning (Mdn [Q1, Q3])	Face-to-Face Learning (Mdn [Q1, Q3])	*p*-value
A	49.50 [46.00, 51.00]	62.00 [60.00, 65.00]	56.00 [52.00, 58.00]	< 0.001
B	51.00 [49.00, 52.00]	63.50 [61.00, 66.00]	53.00 [51.00, 55.00]	< 0.001
C	50.50 [48.00, 54.00]	65.00 [63.00, 69.00]	61.00 [57.00, 62.00]	< 0.001

Table 3 Level of satisfaction with telemedicine competency training by time points for each group, indicating medians, interquartile ranges, and *p*-values for medians

Group	Online/Distance Learning (Mdn [Q1, Q3])	Hybrid Learning (Mdn [Q1, Q3])	Face-to-Face Learning (Mdn [Q1, Q3])	*p*-value
A	58.00 [55.00, 60.00]	74.50 [71.00, 76.00]	60.00 [57.00, 61.00]	< 0.001
B	59.00 [56.00, 61.00]	71.00 [68.00, 73.00]	63.50 [61.00, 66.00]	< 0.001
C	59.50 [56.00, 61.00]	74.00 [71.00, 76.00]	58.50 [58.00, 62.00]	< 0.001

60.00]. At Time Point 2, during hybrid learning, the median score increased significantly to 74.50 [71.00, 76.00], while at Time Point 3, after transitioning to traditional face-to-face learning, the median score was 60.00 [57.00, 61.00]. For Group B, the respective median scores were 59.00 [56.00, 61.00] during online/distance learning, 71.00 [68.00, 73.00] during hybrid learning, and 63.50 [61.00, 66.00] during traditional face-to-face learning. Group C showed similar trends, with median scores of 59.50 [56.00, 61.00] at Time Point 1 (online/distance learning), 74.00 [71.00, 76.00] at Time Point 2 (hybrid learning), and 58.50 [58.00, 62.00] at Time Point 3 (traditional face-to-face learning). For all three groups, the hybrid learning phase (Time Point 2) consistently yielded the highest level of satisfaction, while the online/distance learning phase (Time Point 1) showed the lowest satisfaction scores. The non-parametric Friedman test was applied, and the *p*-values for all groups were below 0.001, confirming that the differences in satisfaction across the three-time points were statistically significant, with hybrid learning being the most preferred mode of instruction for telemedicine competency education.

Discussion

The research results indicate that the satisfaction of medical students with different modes of instruction varies significantly over time. In particular, satisfaction with telemedicine competency education fluctuated depending on the instructional mode over the three-year period. Hybrid learning demonstrated the highest satisfaction levels, while online learning yielded the lowest. Several factors may explain these findings. Hybrid learning likely fostered greater interactivity and student engagement by combining online resources with face-to-face sessions, contributing to a deeper understanding of the material and higher satisfaction levels. A 2021 survey of medical students during the COVID-19 pandemic [12] found that hybrid learning can be beneficial and effective in enhancing academic performance and the quality of learning. Although traditional face-to-face instruction provides more intensive social interaction between students and instructors, which also contributes to student satisfaction, it ranked second in the indicators. For example, a comprehensive review [31] reported that students in hybrid classes experienced lower levels of interaction, engagement, and motivation compared to students in traditional face-to-face settings. However, hybrid learning combines social interaction with the convenience of online resources, which may be highly valued by students. The effectiveness of hybrid learning is contingent on various factors [32], such as the design and implementation of the learning process. Additionally, hybrid learning offers students the flexibility to choose their preferred learning style based on their individual needs. Conversely, online learning may not have been as adaptable to students' preferences, particularly because at the time of the study, online/distance learning had just been introduced and was relatively new and unexplored, which could have impacted the results. Moreover, satisfaction levels could also be influenced by individual preferences: some students may prefer online learning, while others may gravitate towards face-to-face or hybrid instruction [11]. Data suggests that senior students, males, and married students were more likely to have a positive perception of online learning, whereas second-year students showed a stronger preference for hybrid learning [11].

A 2022 review of global educational strategies [1] highlighted the rapid development of innovative approaches during the pandemic, many of which involved the use of digital tools. The review suggests that some of the most effective strategies developed during the pandemic are likely to continue being used in the post-pandemic period. For instance, while the hybrid approach can serve as a model, it requires careful design and flexible tools that allow educators to connect earlier project decisions with the broader distributed environment and emerging activities [33–37]. A trend analysis [38] emphasized that teacher training is crucial to the successful adaptation of blended learning, alongside the adoption of appropriate educational technologies by institutions. This correlates with the need to develop effective programs and elements, as demonstrated in the current research.

A 2020 meta-analysis [3] demonstrated that hybrid learning consistently produced better knowledge outcomes compared to traditional medical education. Furthermore, a 2023 survey of students' opinions on the adopted hybrid learning model [39] found the approach to be generally favorable. In terms of the online/distance approach, a 2020 study [40] identified several challenges faced by students during the COVID-19 pandemic, including communication barriers, difficulties with assessment, the use of technological tools, anxiety or stress related to the pandemic, time management issues, and technophobia. These factors may have influenced the

lower satisfaction scores observed in the online learning phase of the current study, highlighting the need for further research into online approaches post-pandemic. The hybrid model, in contrast, represents a synergy of the strengths of both online and traditional methods [4]. A 2020 study by Al-Balas et al. [10] found that the level of satisfaction with distance learning was only 26.8% among medical students. However, students with prior experience in distance learning and those who actively participated in multimedia sessions and dedicated sufficient time reported significantly higher satisfaction. This underscores the importance of individual student capabilities [11]. Finally, a 2021 study [5] examined the effectiveness and acceptability of synchronous distance education compared to traditional education for medical students. The findings indicated that synchronous distance education was not significantly different from traditional education in terms of effectiveness, but it received higher satisfaction ratings [5], suggesting its potential as an adaptation method in the post-COVID educational landscape.

Conclusions

The results of the study indicated that student satisfaction varied over time: hybrid learning (Time Point 2) resulted in the highest level of satisfaction, whereas online/distance learning (Time Point 1) yielded the lowest. The differences between the time points were statistically significant, confirming the impact of the mode of education on students' perceptions. Hybrid learning emerged as the preferred method, while online/distance learning in 2020–2021 and traditional face-to-face learning in 2022–2023 showed lower satisfaction levels. These results highlight the practical value of hybrid learning for educational institutions, suggesting the need to incorporate more flexible and modern teaching methods. From a scientific perspective, these findings provide a basis for further research on the effectiveness of educational methods and their adaptation in the post-pandemic era. The results highlight the significance of hybrid learning in medical education, particularly in crises such as pandemics. The study is unique in that it provides data on the dynamics of student satisfaction across different learning modes over a three-year period, an area that has not been extensively explored previously. These findings could contribute substantially to current research and literature, offering new perspectives for optimizing educational programs in medical schools.

Limitations

The study spans an extended period, enabling the assessment of changes in student satisfaction across different learning modes. The use of statistical methods and satisfaction scales ensures high reliability and validity of the obtained data. The inclusion of a large number of participants from various universities enhances the generalizability of the results. At the same time, the limitations of this study include the self-report measures developed for the current research; however, this limitation was mitigated through the high quality and careful design of the assessment tools. Additionally, the results may not be widely generalizable, considering that the participants were students from only three medical universities and because the study covers only one educational system. Furthermore, the findings concerning online/distance learning should be viewed in the context of the pandemic, as it was being implemented, and the stress and anxiety levels were higher than normal for everyone, before or after the active phase of the pandemic. This study was not designed to directly compare the modes of education as such. Students did not compare the modes of instruction; rather, they assessed their satisfaction with specific interventions (simulation or telemedicine) across three different time periods, during which three distinct modes of learning—online, hybrid, and in-person—were implemented. While the mode of education may have had a significant impact on satisfaction levels, other factors not examined in this study could also have influenced the results during each period. Another limitation of the research is that although the Friedman test indicated the presence of statistically significant differences among the three-time points, it did not allow for precise identification of which pairs of time points differed from one another. Consequently, the results should be interpreted with caution, and further research employing post hoc tests may be required for a more detailed understanding of the differences between the periods. Future research should focus on testing new ways to adapt medical education to better prepare for new unexpected challenges.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12909-024-06271-8.

Supplementary Material 1

Supplementary Material 2

Acknowledgements
Not applicable.

Author contributions
YZ, TS, XZ, XW, and WH contributed equally to the experimentation. YZ, TS, and WH wrote and edited the article. XZ and XW equally designed and conducted the experiment. XW and WH studied scientific literature about the topic. All authors read and approved the final manuscript.

Funding
This work was supported by the National Natural Science Foundation of China (Grant No.82101416).

Data availability
The datasets used and/or analysed during the current study available from the corresponding author (Wenyu Hu, wenyuhu@gmx.com) on reasonable request.

Declarations

Ethics approval and consent to participate
The authors declare that the work is written with due consideration of ethical standards. The study was conducted in accordance with the ethical principles approved by the Ethics Committee of The First Hospital of China Medical University (Protocol No 56 of 13.06.2023).

Consent to participate
Informed consent was signed by participants.

Consent for publication
Not applicable.

Conflict of interest
The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Competing interests
The authors declare no competing interests.

Received: 25 March 2024 / Accepted: 29 October 2024
Published online: 11 November 2024

References

1. Papapanou M, Routsi E, Tsamakis K, et al. Medical education challenges and innovations during COVID-19 pandemic. Postgrad Med J. 2022;98(1159):321–7. https://doi.org/10.1136/postgradmedj-2021-140032.
2. Sahi PK, Mishra D, Singh T. Medical education amid the COVID-19 pandemic. Indian Pediatr. 2020;57(7):652–7. https://doi.org/10.1007/s13312-020-1894-7.
3. Vallée A, Blacher J, Cariou A, et al. Blended learning compared to traditional learning in medical education: systematic review and meta-analysis. J Med Internet Res. 2020;22(8):e16504. https://doi.org/10.2196/16504.
4. Loda T, Löffler T, Erschens R, et al. Medical education in times of COVID-19: German students' expectations - a cross-sectional study. PLoS ONE. 2020;15(11):e0241660. https://doi.org/10.1371/journal.pone.0241660.
5. He L, Yang N, Xu L, et al. Synchronous distance education vs traditional education for health science students: a systematic review and meta-analysis. Med Educ. 2021;55(3):293–308. https://doi.org/10.1111/medu.14364.
6. Daroedono E, Siagian FE, Alfarabi M, et al. The impact of COVID-19 on medical education: our students perception on the practice of long distance learning. Int J Community Med Public Health. 2020;7(7):2790–6. https://doi.org/10.18203/2394-6040.ijcmph20202545.
7. Dedeilia A, Sotiropoulos MG, Hanrahan JG, et al. Medical and surgical education challenges and innovations in the COVID-19 era: a systematic review. In vivo (Athens Greece). 2020;34(3 Suppl):1603–11. https://doi.org/10.21873/invivo.11950.
8. Mukhtar K, Javed K, Arooj M, et al. Advantages, limitations and recommendations for online learning during COVID-19 pandemic era. Pak J Med Sci. 2020;36(4):S27–31. https://doi.org/10.12669/pjms.36.COVID19-S4.2785. COVID19-S.
9. Kononowicz AA, Woodham LA, Edelbring S, et al. Virtual patient simulations in health professions education: systematic review and meta-analysis by the digital health education collaboration. J Med Internet Res. 2019;21(7):e14676. https://doi.org/10.2196/14676.
10. Al-Balas M, Al-Balas HI, Jaber HM, et al. Correction to: Distance learning in clinical medical education amid COVID-19 pandemic in Jordan: current situation, challenges, and perspectives. BMC Med Educ. 2020;20(1):513. https://doi.org/10.1186/s12909-020-02428-3.
11. Osaili TM, Ismail LC, ElMehdi HM, et al. Comparison of students' perceptions of online and hybrid learning modalities during the COVID-19 pandemic: the case of the University of Sharjah. PLoS ONE. 2023;18(3):e0283513. https://doi.org/10.1371/journal.pone.0283513.
12. Alshamrani KM, Ghulam EM, Alattas M, et al. Transition to remote/hybrid learning during the COVID-19 pandemic among Saudi students of the College of Applied Medical Sciences: a cross-sectional study. Front Med. 2023;10:1257589. https://doi.org/10.3389/fmed.2023.1257589.
13. Hall S, Border S. Online neuroanatomy education and its role during the coronavirus disease 2019 (COVID-19) lockdown. World Neurosurg. 2020;139:628. https://doi.org/10.1016/j.wneu.2020.05.001.
14. Jeong L, Smith Z, Longino A, et al. Virtual peer teaching during the COVID-19 pandemic. Med Sci Educ. 2020;30(4):1361–2. https://doi.org/10.1007/s40670-020-01065-1.
15. Chandra S, Laoteppitaks C, Mingioni N, et al. Zooming-out COVID-19: virtual clinical experiences in an emergency medicine clerkship. Med Educ. 2020;54(12):1182–3. https://doi.org/10.1111/medu.14266.
16. Di Lalla V, Posel N, Gerard IJ, et al. Evaluation of simulation-based virtual patient encounters for learning oncologic emergency management. Int J Radiat Oncol Biol Phys. 2022;114(3):e492–3. https://doi.org/10.1016/j.ijrobp.2022.07.1773.
17. Sandars J, Correia R, Dankbaar M, et al. Twelve tips for rapidly migrating to online learning during the COVID-19 pandemic. MedEdPublish. 2020;9(1):82. https://doi.org/10.15694/mep.2020.000082.1.
18. So HY, Chen PP, Wong GKC, et al. Simulation in medical education. J R Coll Physicians Edinb. 2019;49(1):52–7. https://doi.org/10.4997/JRCPE.2019.112.
19. Plackett R, Kassianos AP, Mylan S, et al. The effectiveness of using virtual patient educational tools to improve medical students' clinical reasoning skills: a systematic review. BMC Med Educ. 2022;22(1):365. https://doi.org/10.1186/s12909-022-03410-x.
20. Shah S, Diwan S, Kohan L, et al. The technological impact of COVID-19 on the future of education and health care delivery. Pain Physician. 2020;23(4S):S367–80.
21. Elshama SS. How to apply simulation-based learning in medical education? Iberoam J Med. 2020;2(2):79–86. https://doi.org/10.5281/zenodo.3685233.
22. Wang Y, Ji Y. How do they learn: types and characteristics of medical and healthcare student engagement in a simulation-based learning environment. BMC Med Educ. 2021;21(1):420. https://doi.org/10.1186/s12909-021-02858-7.
23. Peng Y, Yang L, Qi A, et al. Simulation-based learning combined with case and problem-based learning in the clinical education of joint surgery. J Surg Educ. 2023;80(6):892–9. https://doi.org/10.1016/j.jsurg.2023.03.001.
24. Jumreornvong O, Yang E, Race J, et al. Telemedicine and Medical Education in the age of COVID-19. Acad Med. 2020;95(12):1838–43. https://doi.org/10.1097/ACM.0000000000003711.
25. Shawwa L. The use of telemedicine in medical education and patient care. Cureus. 2023;15(4):e37766. https://doi.org/10.7759/cureus.37766.
26. García-Gutiérrez FM, Pino-Zavaleta F, Romero-Robles MA, et al. Self-reported perceptions and knowledge of telemedicine in medical students and professionals who enrolled in an online course in Peru. BMC Med Educ. 2023;23(1):88. https://doi.org/10.1186/s12909-023-04058-x.
27. Gaur U, Majumder MAA, Sa B, et al. Challenges and opportunities of preclinical medical education: COVID-19 crisis and beyond. SN Compr Clin Med. 2020;2(11):1992–7. https://doi.org/10.1007/s42399-020-00528-1.
28. Shehata MH, Abouzeid E, Wasfy NF, et al. Medical education adaptations post COVID-19: an Egyptian reflection. J Med Educ Curric Dev. 2020;7:2382120520951819. https://doi.org/10.1177/2382120520951819.
29. Barteit S, Lanfermann L, Bärnighausen T, et al. Augmented, mixed, and virtual reality-based head-mounted devices for medical education: systematic review. JSG. 2021;9(3):e29080. https://doi.org/10.2196/29080.
30. Lee J, Choi H, Davis RO, et al. Instructional media selection principles for online medical education and emerging models for the new normal. Med Teach. 2023;45(6):633–41. https://doi.org/10.1080/0142159X.2022.2151884.
31. Li KC, Wong BTM, Kwan R, et al. Evaluation of hybrid learning and teaching practices: the perspective of academics. Sustainability. 2023;15(8):6780. https://doi.org/10.3390/su15086780.
32. Jdaitawi M, Ahmed M, Taamneh M. The factors of individuals and course on students' motivation within hybrid learning process. FWU J Soc Sci. 2023;17(1):18–27.
33. Fawns T, Markauskaite L, Carvalho L, et al. H2m pedagogy: Designing for hybrid learning in medical education. Hybrid learning spaces. Cham: Springer International Publishing; 2022. pp. 61–76.
34. Smolyanova TI, Bagaeva NS, Kolganova MA, et al. Phase I pharmacokinetics study of drug «COVID-globulin» (specific human immunoglobulin against COVID-19). Drug Dev Registr. 2022;11(2):180–6. https://doi.org/10.33380/2305-2066-2022-11-2-180-186.

35. Nikolaeva AM, Ivanov AV, Smolyanova TI, et al. Preclinical evaluation of a New Anti-COVID-19 Intravenous Immunoglobulin. Drug Dev Registr. 2023;12(1):155–60. https://doi.org/10.33380/2305-2066-2023-12-1-155-160. (In Russ.).
36. Spaska AM, Savishchenko VM, Komar OA, et al. Enhancing analytical thinking in tertiary students using debates. Eur J Educ Res. 2021;10(2):879–89. https://doi.org/10.12973/eu-jer.10.2.879.
37. Chu ECP, Spaska A, Monov D, et al. Examining the correlation between salivary cytokine concentrations and CRP in people experiencing social-cognitive stress. Neurol Res. 2023;45(2):160–5. https://doi.org/10.1080/01616412.2022.2126681.
38. Bozkurt A. A retro perspective on blended/hybrid learning: systematic review, mapping and visualization of the scholarly landscape. J Interact Media Educ. 2022;2022(1):1–15. https://doi.org/10.5334/jime.751.
39. Orozco MFS, de González WYE, Marín NP, et al. Depression and opinion of dental students regarding the hybrid learning model during the COVID-19 pandemic. BMC Psychol. 2023;11(1):115. https://doi.org/10.1186/s40359-023-01157-8.
40. Rajab MH, Gazal AM, Alkattan K. Challenges to online medical education during the COVID-19 pandemic. Cureus. 2020;12(7):e8966. https://doi.org/10.7759/cureus.8966.

Publisher's note