Asia Pacific
Academy of Science Pte. Ltd.

Research Article

Information technologies used in medical education

Miriam Janet Cervantes Lopez*, **Raúl de León Escobedo, Arturo Llanes Castillo, Ricardo Salas Flores**

Universidad Autónoma de Tamaulipas, Facultad de Medicina de Tampico, 89339 Tampico, Mexico

* Corresponding author: Miriam Janet Cervantes Lopez, mcervantes@docentes.uat.edu.mx

ABSTRACT

Purpose: The objective of this article is to conduct a literature review to understand and analyze the use of information technologies in medical education. **Design/methodology/approach:** In this documentary article, the method employed focused on the review of various databases (Scopus, Redalyc, Scielo, and Web of Science). **Findings:** As a result, it was found that telemedicine, in particular, has facilitated online consultations and real-time feedback, enhancing the quality of healthcare and promoting continuous professional development. Virtual medical simulations have provided a safe and controlled environment for students and professionals to practice clinical skills, refine techniques, and build confidence before facing real-life situations. Additionally, access to online educational resources, such as digital libraries and medical journals, has expanded access to medical knowledge and enabled students and professionals to stay updated in an ever-evolving field.

Keywords: information; technologies; medical; education

1. Introduction

Currently, due to the isolation caused by the COVID-19 pandemic, people's physical and mental health has been affected. Likewise, the educational environment faced complications because the education system was not prepared to meet the challenges that arose. These challenges encompassed issues ranging from infrastructure, technology, and teaching strategies to a new mindset for students and new teaching methods for educators[1].

These complications resulted in a lower level of learning. For example, in the field of medicine, some students entering their internship had never set foot in an operating room before. This illustrates that online classes alone are not the suitable strategy for subjects that require hands-on experience. Therefore, medical education has incorporated strategies to facilitate professional competence, such as competency-based education. A distinctive feature of this approach is the presence of the student in clinical settings, alongside patients and an educator[1].

Today, medical faculties are integrating technological resources into teaching. These include anatomical models that replace human cadavers with virtual reality, as well as simulation clinics for practical subjects, where physiological and pathophysiological reactions of real patients can be observed. Additionally, in medical-surgical subjects, they are complemented with clinical cases and practical exercises that recreate the

characteristics of a potential patient. This presents a new challenge where it is necessary to identify positive actions that allow the development of new skills, so that medical education is different and aligned with the changes that have occurred, ultimately producing competent students in the present[2].

2. Literature review

Today, online education poses a significant challenge for educational institutions, involving key stakeholders such as students, teachers, and university authorities. The World Health Organization (WHO) refers to the use of Information and Communication Technologies (ICT) in the field of healthcare as eHealth or telehealth, encompassing concepts like Telemedicine, mHealth (the use of mobile devices and applications), and distance learning, also known as teleeducation. According to the WHO, Telemedicine is defined as 'the delivery of healthcare services where distance is a critical factor, by healthcare professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment, and prevention of disease and injuries, as well as for the continuing education of healthcare providers, all in the interests of advancing the health of individuals and their communities'[3].

Based on this, it can be said that telemedicine employs ICT to access remote healthcare services and manage medical care, while tele education is a distance-based health education process that relies on the use of ICT to enable accessible learning for students. Currently, computer networks and new technological applications are essential in both human and professional activities for all individuals[4]. Therefore, it is crucial for medical schools to incorporate the use of ICT in their education to engage students and teachers in scientific research, education, and assessment using technological platforms, rather than solely using them as tools for creating presentations[5].

The use of virtual education can present a significant challenge for higher education institutions, students, and teachers. To make it work effectively, it requires a proper application, which includes a reliable internet connection at both ends (sender-receiver), an appropriate environment for students, familiarity with different virtual platforms by teachers and students, teacher training to structure and deliver distance courses, and adequate technological academic support provided by the university, along with educational content adapted for virtual education[6].

ICT is of utmost importance in various fields of knowledge today, and new technologies have brought about significant changes in how people work, interact, have fun, and, of course, learn and manage their health[7,8]. As a result, questions arise, such as how the teaching-learning process in the healthcare field is evolving and what ideal skills a medical graduate should possess[9]. Both students and medical professionals increasingly turn to online information searches to supplement their knowledge[10,11]. This has led to the emergence of cybermedicine, defined as 'the science that applies internet technologies and global coverage networks in medicine and public health, studies the impact and implications of the internet, and evaluates the challenges and opportunities in healthcare'[12,13].

The use of ICT has facilitated the virtual exchange of information among colleagues without the need for physical travel, saving time and money. Telemedicine is ideal for providing education and training in the healthcare sector through ICT systems, known as tele education. This benefits university students in healthcare programs by offering expert-led training from remote locations. This also includes tele-surgery, where a surgeon remotely conducts live procedures to train a larger number of students without crowding the operating room[14,15].

The use of new technologies in medical education necessitates different teaching contexts and models than traditional ones, where technology is used as an instrument, without altering the basic principles and

objectives of education. In these new contexts, students are more active in their learning, and teachers not only provide information but also act as mentors and guides[16]. The application of telemedicine in the teaching-learning process encompasses various associated methodologies, such as audioconferences and videoconferences that allow real-time interaction with participants, often combined with visual aids, internet-assisted learning, video tutorials, support systems, virtual classes, and human patient simulators that present physical findings and physiological responses for a wide range of clinical scenarios[17].

Today, healthcare educators face new challenges in medical education, as advances in medicine and healthcare increase the demand for training from higher education institutions. This, coupled with the evolution of education, has led to a shift from an instructor-centered approach to a student-centered model, where students have more control over their learning. This has resulted in recent curriculum restructuring based on competencies, emphasizing learning outcomes rather than the process[18].

Learning involves acquiring new knowledge through teaching or experience, and quality in higher education is an ongoing evolution. As teachers' scientific preparation in pedagogy increases, it enhances the relevance and efficiency of education, based on the principles of academic excellence[19]. In the field of medicine, the learning process has evolved over time to meet the need for improvement, and ICT represents a significant opportunity to reinforce education, optimizing practice and reading activities. Presently, students prefer the informative digital environment that allows for greater interaction with electronic devices such as mobile phones, tablets, and the internet[20].

3. Research methodology

As part of the methodology, key terms were employed to search for information related to teaching in medical education through Information and Communication Technologies (ICT). These terms were 'teaching,' 'learning,' and 'Information Technologies,' carefully selected to encompass various facets of educational methodology, specifically focusing on the role of ICT in medical training.

Rigorous criteria were established for the inclusion of works in the review; considered documents had to be available in the databases of Google Scholar, Redalyc, Dialnet, Web of Science, and Scopus. Additionally, the search was limited to works published between 2019 and 2023. This time frame was chosen to ensure the relevance of the gathered information, encompassing recent developments in the integration of ICT in medical education. Exclusion criteria were applied to maintain the quality and relevance of selected documents, excluding works not available on the mentioned platforms, as well as studies published outside the established time frame, and articles that did not significantly address the relationship between teaching in medical education and ICT.

While exhaustive searches were conducted in the mentioned databases, it is important to acknowledge some limitations in the search methodology. For example, the quality and availability of information vary depending on the selected databases, and some relevant works were not adequately indexed in the search platforms. The limited inclusion to specified databases might omit relevant works found in other sources.

The search strategy followed a logical order, utilizing the mentioned key terms and applying filters with commas and asterisks to refine the results. This process allowed for the retrieval of a broad initial set of results, which were then subjected to a meticulous review to ensure the relevance and quality of the selected information. A thorough review was conducted on the 13,100 results in Google Scholar, 100,229 in Redalyc, 38,490 in Dialnet, 11,259 in Web of Science, and 9104 in Scopus, ensuring the selection of pertinent documents and the exclusion of those not meeting the established criteria. This aimed to establish a solid foundation for the research, identifying current trends and developments in the integration of ICT in medical

education.

4. Results

Based on all the studies and compiled information, the teaching methodology of internet-assisted learning using Information and Communication Technologies (ICT) offers a wide range of solutions that enhance knowledge and academic performance. Through this methodology, medical educators can provide opportunities for interactive and self-directed learning, promote active participation, and encourage student motivation. This, in turn, improves the effectiveness of educational interventions and addresses the social, pedagogical, and scientific challenges that have arisen in recent years[21].

The integration of technology into medical education has enhanced the teaching and learning process[22]. The implementation of technological tools in medical education has positively impacted teaching by educators and learning by students. There is evidence demonstrating that the use of technology, through practical interaction with technological instruments, has facilitated medical learning and allowed for training without the risk of incorrect patient interaction[23].

According to Pérez[24], there are advantages and disadvantages of technology, which are presented in the following table (**Table 1**).

Table 1. Advantages and disadvantages of technology.

Advantages	Disadvantages
• They allow the achievement of learning objectives • Facilitate the production of teaching materials • Meet the requirements and expectations of current study programs • Utilize current virtual tools • Promote student participation and research	• The traditional student-teacher dialogue is replaced by virtual language • In closed packages, there is no room for the development of creativity • Virtual media displaces the traditional book • They are exposed to virus information on the internet, and it is possible to lose or damage information • The sources of information are not always reliable

Source: Own compilation, 2023.

In today's globalized society, the proficient use of technology contributes to innovation and improvement in medical science, transforming educational systems and advancing towards constructivist models that place students at the center and enhance their learning abilities in an interconnected environment[25]. In this context, 'virtual learning is characterized by its immateriality, interactivity, autonomy, and digitalization'[26], bringing medical education into the realm of virtual practice campuses that simulate reality, helping to avoid risks to patients and facilitating the acquisition of necessary theory. The interaction between the teacher and the student is mediated by computer-based assistance, with the importance of technological tools lying in their potential for student development, enabling them to become adept in their use and ultimately transforming medical practice into a more effective one.

Surgical simulation is proposed as an alternative in medical education to develop students' skills and abilities. It is currently a valuable aid for learning cognitive skills while allowing students to practice on inanimate objects without affecting patients. It promotes safety by reducing anxiety when carrying out a practice without prior training, simulating real aspects and creating similar situations where students independently confront different practices[27].

As a result, virtual reality emerges as 'a type of computer simulation that recreates environments for a subject to interact with and experience as if it were happening in a real environment'[28]. In other words, it involves the duplication of images that provide individuals with an experience very close to reality through a

set of technological devices. This makes virtual reality a tool that allows students to actively participate while the teacher imparts knowledge and practically demonstrates the same[29].

Virtual simulations in clinical practice have proven to be a valuable tool for medical training and the development of clinical skills. They provide significant opportunities for training and practice across various medical specialties. Therefore, future directions are expected to explore the adaptation and expansion of these tools in areas such as surgery, emergency medicine, obstetrics, among others. The impact of virtual simulations is anticipated to be evaluated through studies analyzing how training based on these simulations translates into improved clinical care and positive outcomes for patients. This includes the reduction of medical errors, safer patient care, and enhanced efficiency in diagnosis and treatment[30].

As the transition to widespread implementation of virtual simulations in clinical practice progresses, it is crucial to identify and address potential barriers. These may include technological limitations, resistance to change among healthcare professionals, budgetary constraints, and the need to establish standards and regulations to ensure the quality and validity of virtual simulations used in clinical settings. Therefore, future directions should consider the integration of emerging technologies, such as virtual reality (VR) and augmented reality (AR), to enhance immersion and the learning experience. This allows for more realistic and personalized simulations, bringing healthcare professionals closer to authentic clinical environments. Additionally, fostering interdisciplinary and global collaboration in the development and implementation of these technologies is essential for their successful integration[31].

Telemedicine has proven to be an invaluable resource in medical training and education, enabling healthcare professionals to access educational resources and training remotely. **Table 2** presents some models of telemedicine use as an educational instrument:

Table 2. Models of telemedicine use as an educational instrument.

Model	Description
Individual–Ad-Hoc–Real-Time	The emergency team responds to a call from a patient with chest pain and transmits an electrocardiogram to the hospital's emergency team for the accurate diagnosis of the patient
Individual–Ad-Hoc–Deferred	Dr. Pérez has a problem with a patient who has a spot on their right forearm that he was unable to identify during the first consultation. He has requested assistance from Dr. Gómez, a dermatologist. Dr. Pérez sends some photographs of the patient's spot by email to Dr. Gómez, who returns the report the following day. If Dr. Gómez were to examine the patient's spot via video conference with the patient present, it would be considered real-time
Individual–Scheduled–Real-Time	Dr. García has a patient who requires an urgent operation that he believes he has not performed a sufficient number of times to feel confident. There is no possibility of transferring the patient to an experienced center. Dr. García will perform the operation under the supervision and guidance of Dr. Hernández in real-time.
Individual–Structured	Dr. Pérez observes a high incidence of hypothyroidism in his area, with which he is not very familiar, and requests assistance and information from the reference endocrinologist. In this program, various members of the primary care team or multiple centers could participate, making it a structured and collective approach
Collective–Scheduled–Real-Time	Dr. González, a cardiovascular surgeon, is going to perform an extracorporeal operation that will be broadcast to several hospitals and observed by different cardiac surgery teams in real-time
Collective–Scheduled–Deferred	Dr. González organizes a clinical session with several surgical teams in different hospitals based on a patient's operation that he performed last week. The session will consist of screening a video of the operation and a discussion of the surgical technique

Source: Own compilation, 2023.

The increasing use of technologies such as telemedicine, virtual simulations, and online educational resources in medical education brings numerous benefits but also raises ethical considerations and encounters limitations and barriers that need to be addressed. In the case of telemedicine, ethical challenges emerge

concerning patient privacy. Therefore, it is essential to establish robust protocols to ensure the security and confidentiality of medical information during virtual consultations and data transmission. Virtual simulations often involve realistic clinical cases, underscoring the importance of obtaining clear informed consent from participants, ensuring their understanding of the simulated nature and potential scenarios they may encounter[32].

Ensuring equitable access to online educational resources is an ethical imperative, as addressing digital and economic gaps is crucial to guaranteeing that all students have access to quality medical education. The lack of access to advanced technologies can limit participation in virtual simulations and telemedicine sessions, impacting students and healthcare professionals in areas with deficient technological infrastructures. The integration of telemedicine, virtual simulations, and online educational resources in medical education offers immense benefits, but successful implementation requires an ethical approach and overcoming identified limitations and barriers. Addressing these aspects ensures effective, equitable, and ethical medical education in the digital era[33]. The following table describes the utility of these technologies in medical education (**Table 3**).

Table 3. Utility of ICT in medical education.

Technology	Description	Advances	Limitations	Advantages
Telemedicine	Enables remote medical consultations	Remote access to medical care	Ethical challenges in patient privacy and interaction quality	Improved accessibility, studies demonstrate effectiveness in follow-up
Medical Simulations	Provides virtual clinical scenarios	Development of practical skills without risks	Lack of real physical interaction	Error reduction, safer and more effective training
Online Educational Resources	Digital Libraries, Online Videos	Access to updated and diverse medical information	Variable quality of information, potential data overload	Flexibility in learning, multimedia resources for clear explanations

Source: Own compilation, 2023.

5. Discussion

The incorporation of Information Technologies (IT) into medical education is a highly relevant and current topic that has significantly transformed the way healthcare professionals acquire knowledge and develop their skills. This technological advancement has sparked numerous important discussions and considerations in the field of medical education. As noted by Grilli, Forestiere & Urango[34], technologies applied to medical education have radically transformed how healthcare professionals acquire knowledge and skills. In this regard, Palacio et al.[35] point out that telemedicine has proven to be an invaluable tool in this process, offering numerous opportunities and advantages for medical education. The ability to access lectures, seminars, and educational programs online has broken geographical barriers, allowing professionals and students from around the world to access high-quality content delivered by experts in their respective fields. This has expanded learning opportunities and fostered collaboration and knowledge exchange on a global scale.

In their research, Espinoza & Segarra[36] mention that telemedicine has facilitated online consultations and mentoring, enabling professionals in training to receive real-time guidance and feedback from experts. This has contributed to improving the quality of healthcare and promoting continuous professional development. Virtual medical simulations have also played a crucial role in medical education by providing a safe and controlled environment for students and professionals to practice clinical skills, refine techniques, and boost confidence before applying this knowledge in real-life situations.

Rodríguez et al.[37] note that access to online educational resources, such as digital libraries, medical

journals, and educational videos, has expanded access to medical knowledge and allowed students and professionals to stay updated in an ever-evolving field. Therefore, technologies applied to medical education, particularly telemedicine, have revolutionized how healthcare professionals acquire knowledge and skills. These tools have provided unprecedented flexibility, accessibility, and learning opportunities, ultimately enhancing the quality of medical education and, in turn, contributing to higher-quality healthcare for the benefit of patients worldwide.

Author contributions

Conceptualization, MJCL and ALC; methodology, RSF; software, MJCL; validation, ALC, MJCL and RdLE; formal analysis, MJCL; investigation, RSF; resources, ALC; data curation, RdLE; writing—original draft preparation, MJCL; writing—review and editing, ALC; visualization, RSF; supervision, RdLE; project administration, RSF; funding acquisition, RdLE. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

References

1. Rose S. Medical Student Education in the Time of COVID-19. Jama. 2020, 323(21): 2131-2132.
2. Hernández GY, López AO, Fernández Oliva B. New Reality in Medical Education Due to COVID-19. Higher Medical Education. 2021, 35(1).
3. Sigueña M, Carlos J. Telemedicine Plan to Improve Healthcare in a Rural Health Sub-Center in Cerecita [Master's thesis]. University of Guayaquil; 2016.
4. Wernhart, A., Gahbauer, S., & Haluza, D. eHealth and telemedicine: Practices and beliefs among healthcare professionals and medical students at a medical university. PloS one. 2019 14(2): e0213067.
5. Korkmaz, C., & Correia, A. P. A review of research on machine learning in educational technology. Educational Media International. 2019. 56(3): 250-267.
6. Renzo ACC, Medina QCI. COVID-19 and Education in Medical Students. Cuban Journal of Biomedical Research. 2020, 39(2).
7. Adell SJ. Trends in Education in the Society of Information Technologies. EDUTEC: Electronic Journal of Educational Technology. 1997.
8. Santos SE. The Historical Perspective of Science-Technology-Society Relationships and Their Role in Science Education. Electronic Journal of Science Education. 2003, 2(3): 240-246.
9. Viloria NC. Information Technologies for Education, Research, and Application in the Health Area. Advantages and Challenge. Revista Salud Uninorte. 2009, 25(2): 331-349.
10. John NW. Cybermedicine-What is possible, and is it useful? In: Proceedings of the 2005 International Conference on Cyberworlds (CW'05).
11. Konlg S, Cervantes R, Molina M, Vargas P. ICTs and the Healthcare System in Chile. Spanish Society of Health Informatics. 2007, 64: 30-38.
12. Millet A. The Advent of Cybermedicine. Scientific World. 2000, (211): 66-67.
13. Eysenbach G. Towards the Millennium of Cybermedicine. Journal of Medical Internet Research. 1999, 1(S1).
14. Ibáñez CR, De Cadena ÁZ, Zea AT. Telemedicine: Introduction, Application, and Development Principles. Ces Medicine. 2007, 21(1): 77-93.
15. Ochoa G, Daza M, Archila M, et al. Telecommunications, Telemedicine, and Health Reengineering. UC Engineering. 1998, 5(1).
16. García BM. The Educational Value of Telemedicine. Medical Education. 2006, 9: 38-43.
17. Muramoto ML, Campbell J, Salazar Z. Provider Training and Education in Disease Management: Current and Innovative Technology. Disease Management & Health Outcomes. 2003, 11: 633-645.
18. Díaz MVE, Orellana DRG, Reyes KLG. Importance of the Use of Telemedicine Platforms in Pre-Professional Medical Education. Pro Sciences: Journal of Production, Sciences, and Research. 2020, 4(31): 79-87.
19. Quintana GML, Pujals VN, Pérez HG, et al. Medical Education Training from the National School of Public Health (ENSAP). Higher Medical Education. 2016, 30(1).
20. Del Vasto PMH. Influence of Information and Communication Technologies (ICT) on the Teaching-Learning

Process: An Improvement in Digital Skills. Revista Científica General José María Córdova. 2015, 13(16): 121-132.

21. Agámez LS, Aldana BM, Barreto AV, Santana GA. Application of New Information Technologies in Medical Education. Revista Salud Uninorte. 2009, 25(1): 150-171

22. Lizaraso CF. New Communication Tools Favor Medical Education. Horizonte Médico (Lima). 2014, 14(2): 4-5.

23. Martin GH, Canchola VHO, Mayén JVA. Use of Information and Communication Technologies (ICT) in Medical Residencies in Mexico. Acta Médica Grupo Ángeles. 2017, 15(2): 150-153.

24. Pérez MM. Current Use of Information and Communication Technologies in Medical Education. Herediana Medical Journal. 2017, 28(4): 258-265.

25. Colorado-Aguilar, B. L., & Edel-Navarro, R. La usabilidad de TIC en la práctica educativa. Revista de Educación a Distancia (RED). 2012. (30).

26. Kononowicz, A. A., Woodham, L. A., Edelbring, S., Stathakarou, N., Davies, D., Saxena, N., ... & Zary, N. Virtual patient simulations in health professions education: systematic review and meta-analysis by the digital health education collaboration. Journal of medical Internet research. 2019. 21(7): e14676.

27. Molina, J., Silveira, E., Heredia, D., & Fernández, D. Los simuladores y los modelos experimentales. REDVET. 2012.

28. Pérez-Salas, C. P. Realidad virtual: un aporte real para la evaluación y el tratamiento de personas con discapacidad intelectual. Terapia psicológica. 2008. 26(2): 253-262.

29. Carbonell, M. A. V., & Silva-Ortega, J. I. Tendencias y características de la realidad virtual: Una revisión de la literatura entre los años 2017 y 2018. Computer and Electronic Sciences: Theory and Applications. 2020. 1(1): 36-70.

30. Cartagena MR, Velandia MR, Cespedes CLO. Simulation and virtual reality in teaching and learning processes in health education. REDIIS/Revista de Investigación e Innovación en Salud. 2023, 8.

31. Cuan JD. The metaverse and artificial intelligence in higher education. Review of success cases. Experior. 2023, 2(1): 66-74.

32. Magalhães dos Santos WO. Bioethical aspects related to the use of information technologies through telehealth: A systematic review.

33. Andocilla I, Mayorga T, Perez M, Vivanco H. Educational approach on the digital divide and neuroscience. July. 2023, 23: 555.

34. Grilli MN, Forestiere OÁ, Uranga A. e-Learning in Medical Education. 2022.

35. Palacio-Uribe J, Duque-Ramírez M, Duque-González L, Ocampo-Salgado C. Cardiac Rehabilitation: An Accelerated Transformation During the COVID-19 Pandemic. Colombian Journal of Cardiology. 2021, 28(4): 360-365.

36. Espinoza-Torres D, Segarra-Oña M. Identification of Key Elements in the Entrepreneurship-Knowledge Relationship: Analysis and Modeling of the Underlying Structure. Youth, Entrepreneurship, and University: A Three-Way Challenge. 2019, 20: 338-361.

37. Rodríguez CDC, Sánchez JAC, Melo JIG, Cuevas JRT. Telemedicine System Based on a Service-Oriented Architecture Applied to Physical Rehabilitation. University of Valle; 2020.