Chapter

Medical Education Technology in Resource-Limited Settings

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Abstract

The integration of information and communication technology (ICT) in medical education is crucial to meet the evolving needs of the global population and ensure competency among healthcare trainees. In low- and middle-income countries (LMICs), where resources are limited, leveraging advanced ICTs has the potential to revolutionize medical education by promoting student-centred learning through asynchronous and distributed access. The recent introduction of artificial intelligence (AI) = in medical education has transformed learning into a personalized experiences, virtual simulations, and real-time feedback. Our experience with use of simple technology in Uganda serves as a prime example of how innovative technologies are being utilized to enhance medical education in a LMICs setting. Our experience in the implementation of interactive displays in simulation training and the establishment of low-cost content production studio has significantly improved trainings and learnings. By integrating these technologies closer to the learning environment, students can access information before or after interacting with their teachers, engage in higher cognitive activities, and stimulate problem-solving skills. The success of these initiatives demonstrates their potential for adoption to elevate the quality of medical education in LMICs. Embracing ICT in medical training not only bridges educational gaps but also fosters inclusive and equitable access to resources in LMICs.

Keywords: content production studio, medical educational technology in Uganda, simulation training, digital divide, medical training in resource limited settings, interactive screen

1. Introduction

The future medical needs of the ever-growing global population necessitate a significant overhaul in medical education to ensure competency. Efforts should be directed towards promoting student-centred learning methods, which have proven to be more effective than teacher-centred ones. In this era, advancement of information and communication technology (ICT) has proven imperative in offering transformative learning avenues for instance producing, distributing, and accessing educational content [1], including within clinical environments [2]. Despite challenges in resource-limited settings, the adoption of technology holds promise in overcoming barriers to access and enhancing quality of medical education. Use of personal computers, projectors, interactive screens, and the Internet has revolutionized the teaching and learning of medicine. Recent innovations in artificial intelligence, such as machine learning and large language modelling, have presented a challenge to educators, as students can now access knowledge and instructions at their own pace and convenience. This necessitates a shift in the delivery of educational content, requiring educators to focus on application, analysis, evaluation, and creation, as outlined in Bloom's taxonomy [3]. In this chapter, we discuss the use of ICT in medical education and reflect on our experiences in introducing some simple but advanced educational technologies in Ugandan contexts and highlight the reasons for the low uptake of these technologies in low resource settings.

2. Medical education and information and communication technology

The primary aim of most medical education curricula is to ensure the successful achievement of specific learning outcomes, leading to the development of competent students. These achievements heavily depend on finding a balance between the workload and the time available for students [4], as well as the methods of content delivery. ICT is an innovative tool that can be used to make learning active, particularly by fostering student-centeredness integrating it closer to the classroom or clinical patient environment. This allows students to access information before or after interacting with faculties [5]. Moreover, ICT can also be harnessed to create activities that engage students' cognitive processes, ensuring that their natural responses are stimulated to solve problems [6].

Despite the challenges posed by limited resources, medical institutions in low-resource settings have established educational technology or media centres to harness the power of ICT in education. These initiatives aim to bridge the gap between traditional and modern teaching methods, ensuring that students receive quality education regardless of their geographic location or access to technology.

2.1 The digital divide

The fulfilment of technology in education aligns with the United Nation's Sustainable Development Goal (SDG) 4, ensuring inclusive and equitable education and promoting lifelong learning opportunities, despite the absence of a specific target for educational technology in the SDG. The production of accessible educational content without restrictions to institutions or geographic areas help reduce inequality in access to educational resources. Advancements in technology have innovatively enhanced the delivery of curricula in many institutions, promoting more effective learning methods.

Regrettably, not all institutions have the luxury of investing in ICT infrastructures and skilled man powers [7, 8]. Even among those that have heavily invested, not all students or faculties have access to ICT. Additionally, cultural and socioeconomic factors may influence the acceptance and implementation of new technologies [9]. This has resulted into some institutions using more ICT compared to others and among some students with technology privileges compared to others. This creates a digital divide which is the gap between those with and those without access to ICT, a situation particularly evident in LMICs, such as Uganda.

The digital divide in low-income countries can be classified into the following categories. Firstly, there is a divide due to limited or lack of access, where poor students may not have smartphones or personal computers, limiting their access to ICT-related educational contents at their own time, pace, and place. Additionally, divides exist due to lack of or failure to maintain ICT infrastructures. More so, costly and unreliable Internet connectivity further exacerbates the digital divide, affecting distributed and asynchronous access.

Furthermore, there is a divide due to the generational gap, with different generations (X, Y, and Z) bringing unique characteristics and teaching/learning preferences. Generation X (born between 1965 and 1980) [10] may prefer a more independent learning approach and might have challenges using technology, potentially impacting the quality of educational materials they produce if they become educators. Generation Y (born between 1981 and 1996) [10] are often tech-savvy and respond well to interactive and technology-enhanced learning experiences. Many educators belonging to this generation are able to navigate technology and incorporate it into their teaching tools. Generation Z (born between 1997 and 2012) [11] are the true digital natives comfortable with technology from a young age, preferring engaging and visually illustrative ICTs content. Educators can take these generational traits into account when designing curriculum, selecting teaching methods, and incorporating technology into medical education to better meet the needs of learners from each generation.

2.2 Medical education technology

In the ever-evolving field of medical education, the integration of technological advancements is paramount in ensuring that healthcare trainees receive comprehensive and up-to-date training. ICT plays a vital role in various aspects of medical education, spanning from content creation, presentation, dissemination, collaboration, and organization. A wide range of ICT tools have been employed in medical education, with ongoing evolution from ownership-based systems where educational materials are stored on diskettes, CDs, and hard-disks to accessibility platforms through browsing or searchable online/offline materials. The Internet has been a catalyst in this evolution, leading to the implementation of learning management systems (such as Moodle, Blackboard, and Canvas) and the establishment of educational technology or media centres.

Although the traditional didactic lectures remain the primary method of instruction for knowledge transfer in most medical educational institutions including those in low-income countries [12], more newer instruction methods are available to supplement this. Methods such as the case-based, group-based student-led tutorials, and portfolio-based learning supplement didactic lectures in knowledge transfer. Moreover, clinical and procedural skills acquisition is facilitated through the traditional bedside teachings and supplemented by skill-based or case-based simulations.

All these learning methods can be enhanced through the integration of ICT inside the classroom and or clinics [13]. With the aid of audio-visual recordings, rare clinical cases or procedures can be archived and replayed multiple times offering learners invaluable learning opportunities. More advanced educational technologies can offer improved presentation features, including embedded videos, hyperlinks, and commands within presentations. They can also provide advanced tools such as audience engagement tools, writing screens, and screen capture methods, as well as enable collaborative annotation and leverage social media. For all these to be fully utilized in a low-income country such as Uganda, the ICT should be adaptable and accessible to both students and their instructors.

The theory of perceived attributes to innovation [14] can be used to illustrate the uptake of ICT innovation in medical education in LMICs. According to this theory, an individual is more likely to adopt a specific innovation if it possesses certain attributes. The theory proposed a five levels attribute that are illustrated in **Figure 1**.

2.3 Theory of perceived attribute to innovation

Comparative advantage refers to how much better an innovation is compared to existing technologies. Innovations that allow for reuse, redistribution, asynchronous access, and increased interactivity are more likely to be embraced by students and educators. Compatibility is key; technologies like lecture production gained popularity post-COVID-19 due to lecturers' familiarity with virtual platforms. The complexity of an innovation matters; simpler technologies like Zoom lectures are preferred over complex studio setups, impacting adoption rates. Triability, or the ease of trying out an innovation, plays a role in acceptance. Lastly, observable positive results increase the likelihood of adoption. In the realm of medical education, simplicity and familiarity are crucial for uptake of ICT platforms.

2.4 Electronic learning platforms

Electronic learning (e-learning) is one of the tools that has been embraced in these settings, its use intensified during the COVID 19 pandemic, and it covers a spectrum of activities involving use of technology to support parts of learning or instruct an entire curriculum [15]. In medical education, e-learning takes various approaches such as blended learning, Web-based learning, eTutor/eMentor programs, simulations, and use of multi-media software. These platforms leverage technology to tailor educational content based on the learner's progress, ensuring that the curriculum remains relevant and engaging. In resource-limited areas, where physical textbooks may be scarce, digital platforms offer a scalable solution, providing access to a vast array of medical resources.

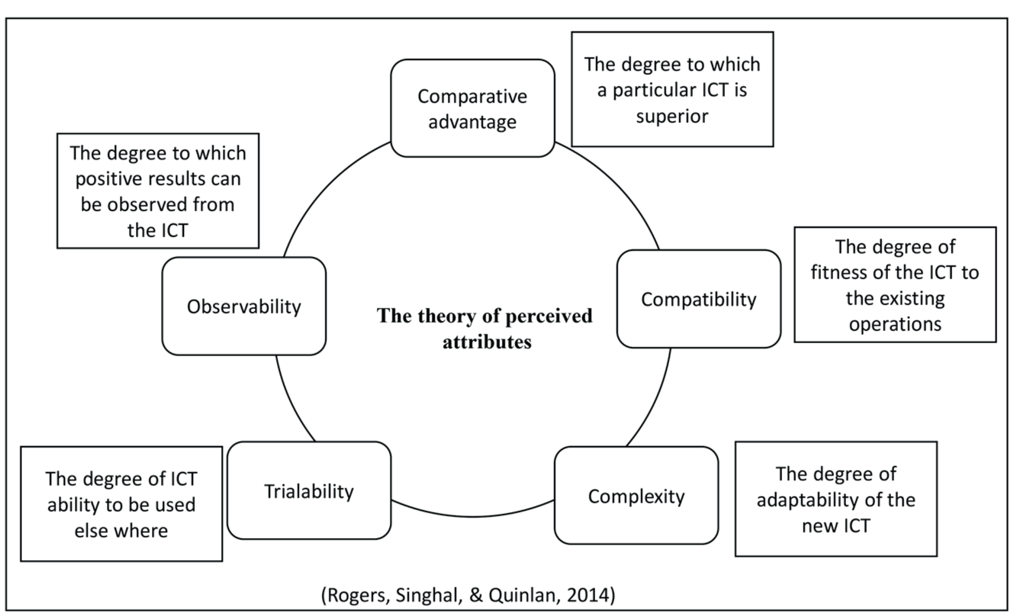


Figure 1.
Theory of perceive attribute to an innovation.

2.5 Mobile learning apps

Recognizing the widespread availability and affordability of smart mobile phones, the development of medical learning apps has proven to be one of the most effective means of instruction. Popular apps include Medscape, UpToDate, Coursera offers a flexible, convenient, and cost-effective learning platforms compared to paper-based approaches allowing students to access educational materials anytime and anywhere [8]. Additionally, interactive features such as quizzes, and virtual case studies enhance the learning experience, making complex medical concepts more digestible.

With increasing digitalization and technological enhancement in the learning Apps, medical educators and learners can benefit from both self-directed as well as collaborative learning. Literatures have shown that digital collaborative learning has better prospects in enhancing students' knowledge and competence compared to traditional methods of instruction. In a meta-analysis of five randomized control trials involving 647 nursing students, digital collaborative learning has been shown to enhance nursing students' interaction and collaborative skills, problem-solving skills, satisfaction, and motivation for learning [16]. Online or in-apps platforms that facilitate group discussions, collaborative projects, and knowledge sharing bridge the geographical gaps in resource-limited areas. These platforms also serve as a space for peer support and mentor, creating a sense of community among learners.

2.6 Artificial intelligence in medical education

In resource-limited settings, the integration of artificial intelligence (AI) into medical education is transformative, addressing enduring challenges and significantly improving the training of healthcare professionals [17]. AI technologies provide personalized and accessible learning experiences, with virtual simulations powered by AI algorithms offering crucial platforms for hands-on skills development. Overcoming resource constraints, these simulations facilitate repetitive practice, fostering mastery and confidence among medical students. The introduction of AI also introduces real-time feedback mechanisms, particularly valuable in settings where expert faculty is scarce. Embracing innovative technologies in resource-limited environments contributes to a more inclusive and equitable medical education landscape, and ensuring learners can access cutting-edge training resources regardless of geographical or financial constraints. As a seasoned medical and clinical educator, advocating for the strategic incorporation of AI into the curriculum becomes imperative for maintaining adaptive, effective, and globally accessible medical training [18].

Web-based and app-based AIs play an integral role in providing collaborative intelligence to enhance medical education [19]. These technologies seamlessly integrate with educational platforms, creating a collaborative ecosystem that enriches the overall educational journey for medical students. Augmented intelligence, facilitated by these AIs, assists learners in accessing extensive medical information, tailoring content to individual needs, and providing personalized study plans based on performance assessments. Within this collaborative intelligence framework, Web-based and app-based AIs foster interaction and engagement among learners, featuring interactive simulations, virtual case studies, and collaborative problem-solving exercises. By encouraging collaboration, these AIs simulate real-world medical scenarios, enabling students to work together, share insights, and collectively deepen their understanding of complex medical concepts. Consequently, Web-based and app-based AIs not only enhance individual intelligence but also cultivate collaborative intelligence, essential for teamwork and interdisciplinary communication in the medical field, optimizing the learning experience for future healthcare professionals [20].

2.7 Simulation-based technology

Simulation in medical education is a humane form of training in which learners are exposed to a controlled environment of real-life scenarios with room for learning from their mistakes. In resource-limited areas where resources for practical training may be scarce, simulations and virtual reality play key role. This not only supplements traditional training but also allows students to practice and refine their skills without the need for expensive equipment or cause harm to patients. The simulation environment encourages repetitive practice, constructive feedback, individualized learning, and variable clinical scenarios with defined outcomes [21].

Simulation may involve technology utilization and task complexity, aimed at equipping learners for clinical work, including managing workload and workflow [22]. It prepares students for the challenges they will encounter in real-world medical practice which include clinical skills, emergency response, communication skills, leadership initiatives and chain of command, critical thinking, problem-solving, decision-making, crisis response, and ethical considerations [23].

2.8 Simulation training at Gulu University in Uganda

Recognizing the crucial needs for the inclusion of technology into medical education, even in resource-limited settings [24] such as in Uganda, Gulu University Simulation Laboratory, was established in the Faculty of Medicine to offer a low-medium fidelity audio-visual simulations. More advanced technological option involved the use of a large interactive screen that links audio-visual simulation debriefs, the Web, and computer creating a seamless learning platform.

Gouzi et al. [25], illustrated the use of interactive screens as an essential tool for immersive medical training among undergraduate students. In their experiment, they engaged medical students in clinical reasoning exercises, where case scenarios, resulting clinical symptoms, tests, and hypotheses were mapped by students onto the interactive screen display. They found that learners demonstrated increased clinical reasoning [25]. This aligns seamlessly with simulation-based methodologies, emphasizing the critical need for such approaches in medical education. Our interactive screen **Figure 2** combines a display panel with touch-sensitive technology, enabling users to engage with digital content in a dynamic and hands-on manner. The device is versatile and surpasses traditional screens, projectors, or smart whiteboards, providing enhanced functionality and promoting engaging and collaborative user experiences. Its integration into the simulation technology has enabled us to provide a real-time audio-visual experience for both simulation and debrief sessions. This not only enhances trainees engagement but also transforms passive observation into active learning, fostering critical thinking, problem-solving, and skills acquisition.

The use of semi-automated medium fidelity manikins and high-quality recordings contribute to an immersive and effective participatory learning atmosphere. Post-simulation, the students that participated take centre stage during debriefing sessions, and their recorded sessions are played by the simulation assistant for critiquing. Thereafter, the team in the simulation room has the opportunity to share their experiences, lessons learned, and challenges they experienced—thereafter the faculty

Figure 2.
Interactive screen being used during a simulation training to illustrate the process of knot tying.

together with the simulation assistants aid students to learn from their experiences, weakness and build on their clinical skills.

The interactive screen (**Figure 2**) emerges as powerful tool providing a platform for clear drawings and annotations and illustrations of information or procedures that are difficult to illustrate using the traditional display technology. This not only reforms medical education but also opens avenues for future research in medical education within resource constrained settings for innovative teaching methodologies. The intuitive touch interface simplifies navigation and interaction, making it user-friendly and accessible to individuals with varying technical proficiency just like a screen touch laptop and associated with better knowledge and skills retention due to active engagement as was described by Ref. [26].

2.9 Low-cost content production studio

Castillo and others in 2021 describe the process of how low-cost educational content is produced; the three phases are preproduction, production, and postproduction [27]. Although a variety of content recording options has been used ranging from simple setups, such as using a webcam and microphone, to more sophisticated setups with professional recording equipment and studios. Our experience in the production of content involved simple interface as illustrated in **Figures 3** and **4** below. The studio is configured to enable users capture video and audio signals using different sources of equipment enabling recording, livestreaming, storage, and playback of audio-visual signals (**Figure 3**). The production of content in the studio can vary depending on the context, platform, and the preferences of the faculty or instructor.

2.10 Content production setup

Our setup involves a simple but user-friendly recording design which integrates audio and video inputs to create a unique output. The video signals come from up to three different cameras depending on the complexity of the recording and the desires

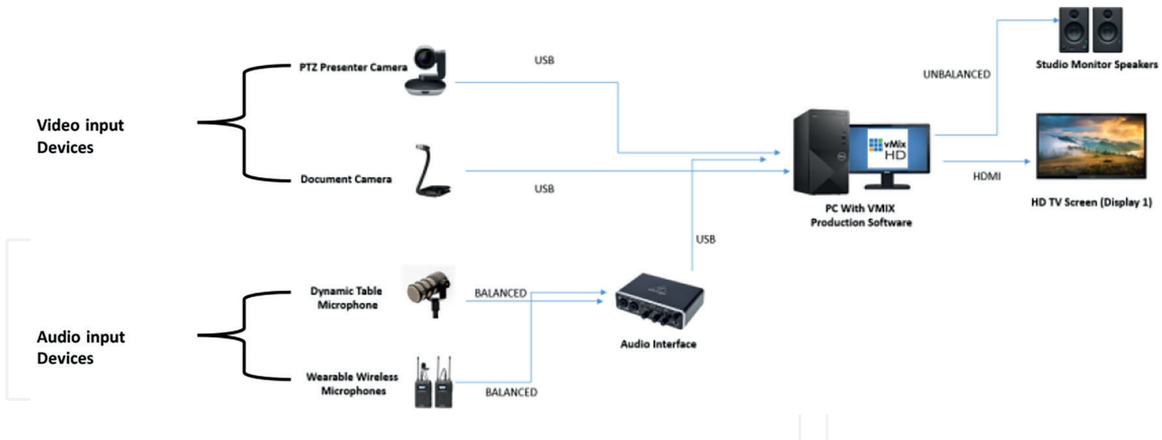
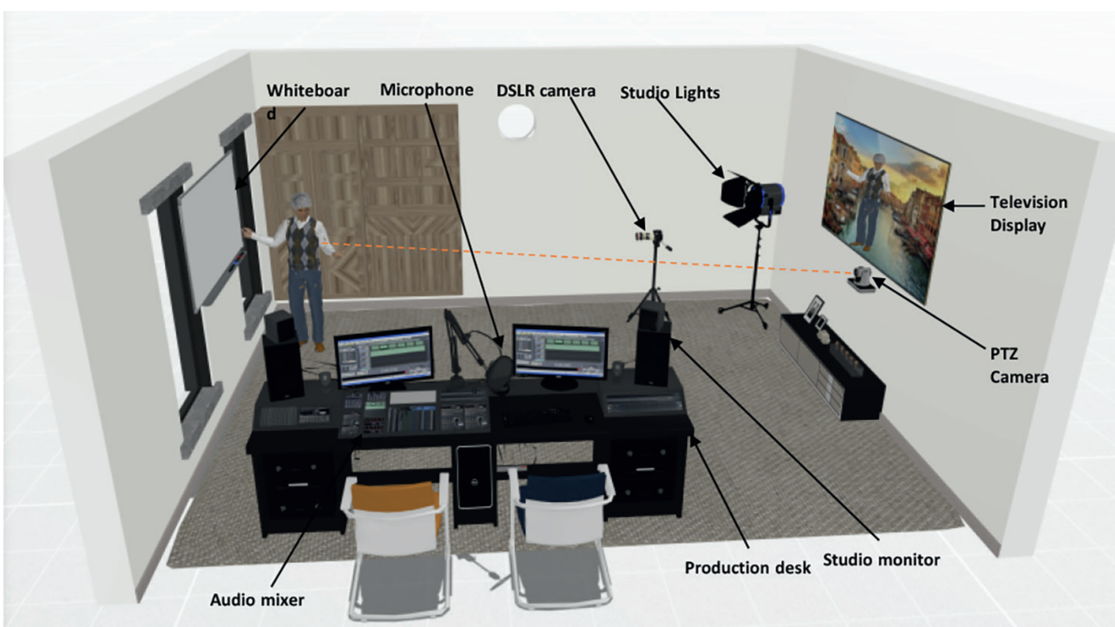


Figure 3.
Recording solution illustration.



DSLR- Digital single lens reflex camera

Figure 4.
Artistic impression of the content production studio.

of the faculty in illustrating a particular detail. As illustrated in **Figure 3**, the video signals come from 1) document camera that captures video signals of different physical media like paper articles or illustration and objects and send them to the computer. 2) Pan Tilt and Zoom (PTZ)) camera, a dynamic tool controlled using a remote and can be used to pick video signals when a faculty is demonstrating or illustrating on whiteboards giving a feel of classroom setup. 3) Digital Single Lens Reflex (DSLR) camera is movable gadget that is varied depending on the direction of the video signals intended and can be used to record off studio contents.

The audio input sources comprise of dynamic unidirectional microphone for PowerPoints voiceovers and wireless microphone which can be worn by the user especially when they are making a presentation on the white board. All the microphone signals fed into the audio interface (**Figure 3**) before being relayed a computer for processing. The video and audio signals are integrated into a computer using a commercial Vmix production software. For controlled production, the audio-visual signals being recorded are relayed on to the television screen and sounds are monitored through studio monitors (**Figure 3**).

2.11 Content production process

Pre-production: Faculties typically start by outlining the topics they want to cover in their contents. They may write scripts, create slides, notes, or other materials to guide their presentation.

Production: Faculties may record their contents in a single take or break them down into smaller segments. With the help of additional mobile camera and a dedicated production assistant, clinical cases and procedures can be recorded even in wards or procedure rooms.

Postproduction: Post-production editing may be done to improve the overall quality of the contents. This involve removing redundant recordings, enhancing audio, or adding visual effects. Commercial editing software like Adobe Premiere, Movavi, or other video editing tools has been used as was elsewhere [28]. The editing is done either in the presence or under the guidance of the faculty involved in the production of the subject contents. The produced and edited contents are then uploaded to the chosen platform. This can be a learning management system (LMS), video hosting service like YouTube, or a specialized educational platform. In our case, the contents are uploaded in these two YouTube channels: https://youtube.com/@gusrhrcavstudio?si=85PZPB1-d2G6gV4x_and_UCumF7dQk1usZtzjZnHNOnhQ.

With online distribution platforms, educational contents produced in our studio is accessible to a global audience. This expands the reach of educational resources, reaching learners who may be geographically distant from traditional educational institutions. These innovative approaches can enhance the learning experience and provide students with a broader range of resources. Pre-recorded content saves time for educators who might otherwise spend a significant portion of class time on repetitive explanations. Additionally, it can be a cost-effective way to deliver high-quality learning materials without the need for continuous live presentations. Conclusively, the content production studio has the potential to positively impact learning by creating engaging, flexible, and inclusive educational content that aligns with diverse learning styles and preferences in low-income countries. This innovation is cost effective and user friendly and can be replicated in educational institutions in many settings.

3. Conclusion

The integration of ICTs in medical education offers a promising avenue to enhance learning experiences, promote student-centred approaches, and bridge educational gaps in healthcare training. The utilization of ICT tools like interactive displays, content production studios, and virtual simulations not only revolutionize content delivery but also foster critical thinking and problem-solving skills among students. While challenges such as the digital divide persist, efforts to leverage ICTs in medical education, as demonstrated in Ugandan contexts, exemplify the potential for technology to improve training outcomes and prepare healthcare professionals to meet the demands of a rapidly evolving healthcare landscape. Embracing innovative technologies and adapting teaching methodologies to accommodate diverse learning styles are crucial steps towards ensuring the competency and readiness of future healthcare providers.

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Conflict of interest

The authors declare no conflict of interest.

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