Exploring Augmented Reality For Early Clinical Exposure Of Healthcare Students: A Review

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ABSTRACT
Early Clinical Exposure (ECE) is a pedagogy to develop confidence and competence in Medical and Allied Health students. Challenges in conventional teaching include less clinical access, varied patient cases, and potential risks to students and patients. This study explores Augmented Reality (AR) as a tool for ECE. It highlights AR's potential to enhance students' understanding, skills acquisition, learning outcomes, motivation, and confidence. Though AR is beneficial in improving learning outcomes, it can only be an additive tool, without replacing traditional teaching. Further research is essential to formulate standardized policies, and implementation guidelines, reduce costs, and evaluate long-term effects on clinical expertise.

1. Introduction

Medical and Allied Health education is constantly advancing to meet the ever-changing complex needs of the healthcare system. With these changes, there is a lot of expectation by and from the students to deliver better patient care. These are the prime reasons for transformation in the methods of the teaching-learning process. Inconsistency and variability in clinical training, exposure, and experience are major global challenges in medical education (1). These challenges contribute significantly to the quality of education and competency of healthcare professionals. With the increasing need to strengthen the healthcare system, there is a need to multiply the reach of healthcare services and staff to all corners. As these professions are patient-centric, much clinical exposure is needed to get well-versed with the equipment, therapies, and protocols (2). However, in the present scenario, they are been taught via conventional methods which might prove to have a gap in theory and practical knowledge needed to handle the patient.

Multiple reasons such as geographic location, availability of patients, and capacities of the healthcare institutes contribute to restricted access to diverse clinical cases (3). Students who study in low-resource settings, face difficulties in getting first-hand experience with a wide range of medical conditions. This contributes to limited exposure to a varied spectrum of patients and scenarios they might encounter in the future. It eventually increases the difficulty of the students by creating a significant gap in the knowledge, skill, and competency required for safe and effective patient care and healthcare delivery (3). The practical or clinical training model of novice students in medical education is demanding in terms of time, and resources, thereby overburdening the healthcare system (3). This also leads to a situation where students do not receive sufficient supervision or feedback.

Another hurdle faced by novice students is adjusting to the new environment and ethical concerns involved while handling the patients with a constant fear of violating patient safety and quality care (4). Moreover, a rapid shift in medical advancements and incrementing complexities of healthcare delivery systems demand the curriculum to evolve continuously (5). However, many institutes find it difficult to stay updated with this rapid pace, leading to outdated teaching methods that struggle to prepare students for the realities of healthcare. These challenges are multiplied due to the rising emphasis on competency-based education (6). Students are stressed due to the change in pattern and find it difficult to cope up with the syllabus (7). The expectation of achieving specific outcomes in competency-based education requires access to good quality, standardized learning experiences and exposure that the current teaching-learning methods lack in providing consistently (8). Consequently, there is an increased acknowledgment of the need to integrate novel teaching methods that can overcome these current shortcomings, be more adaptable, scalable, efficient, and interesting

to teach the students. Integration of technology can be one of the probable solutions to overcome these limitations.

1.1Integration of Technology in Education

In the 21st century, also popularly known as the era of technology, there is a wide involvement of technology in almost every aspect of human life. Technology can be used in the following ways in education technology: as curriculum integration, as a teaching aid, as a teaching-learning strategy, and as a medium to enhance learning process. By incorporating technology, education has changed from being passive and reactive to participatory and aggressive (9). In both corporate and academic environments, education is crucial (10). In the corporates, education or training helps in improving the work by letting the workers work in a new and better way (11). In the academic setting, education or training helps in generating curiosity in the minds of the learner. In either scenario, using technology can improve how well learners comprehend and remember ideas (10).

Education Technology is the term used, which means utilizing all forms of contemporary media and resources for educational purposes is known as education technology (12). Experts recommend education technology as one of the possible tools for effectively and efficiently delivering education (13). If the study materials created with/integrating technology are carefully designed and implemented, they have the potential to speed up, boost, and broaden the positive impact of powerful learning principles (14). Since learning cannot be directly observed, research on it typically yields models and conclusions that evolve.

Advantages of Education Technology (12):

- With the use of technology, learning and experiences can be personalized to be more interesting and useful.
- Utilizing a wide range of digital learning tools and resources to demonstrate mastery with challenging concepts and information, technology may support the organization of learning around real-world issues and project-based learning.
- With the help of technology, learning can be extended beyond the four walls of the classroom, and grab the opportunity for learning from various other resources that in out of the classroom setting.
- Use of technology enables an individual to pursue both passion and personal interests.
- When technology access is fair, it can reduce the digital divide and give every learner access to transformative learning possibilities.
- It aids in time, energy, and resource conservation for both students and teachers. To fill the implementation gaps of ECE in healthcare education, advanced technology can be integrated to offer individualized, immersive, and interactive learning experiences. Simulation-based learning, telemedicine platforms, and mobile learning.

1.2Early Clinical Exposure (ECE)

ECE may be used as a pedagogical strategy in healthcare education. It exposes students to clinical settings and experiences at an early stage of their study (15). Countries across the world have integrated various activities to expose students to clinical experiences. Thus, the terminologies used to describe the idea of obtaining early practical experiences also differ such as early integrated patient contact, early patient experience, early clinical exposure, early patient contact, early practical experience, early clinical experience, learning from early hands-on experience, early clinical contact, early patient encounter, and early student patient contact (16). ECE has been proven to enhance students' attitudes towards learning due to the integration of basic and clinical sciences, and it offers insights into psychosocial aspects of patient care (17). It has helped in imbibing the required professional attitudes among future professionals. It helps students develop their communication and foundational clinical skills, contextualizes their learning, increases their level of curriculum satisfaction, and lessens the anxiety associated with seeing patients (18). ECE may also be advantageous to populations, patients, healthcare organizations, and instructors. Thus, "early clinical experiences have positive effects on knowledge and skill development as well as affective and cognitive outcomes" (16). Healthcare education has traditionally emphasized classroom instruction in the early years, with little to no exposure to real-world clinical settings until much later in the training process (19). Nonetheless, by giving students the chance to see and take part in clinical activities from the beginning of their study, ECE programs seek to close the gap between Theoretical knowledge and practical abilities with the following advantages:

Relevance: ECE assists students in comprehending how the theoretical ideas they study in the classroom are

applied in real-world situations. Students learn more effectively and understand content better as a result of this (20).

- Professionalism: Early exposure to clinical settings aids in the development of students' professionalism, empathy, and communication abilities—all of which are critical for healthcare workers (18).
- Clinical Skill Development: ECE helps students to develop basic clinical skills under the supervision of trained experts (21).
- Confidence Building: Involvement in clinical scenarios, helps students gain confidence in their work, skills, and abilities to make them accountable for future responsibilities.

Careful planning and collaboration between educational institutions and healthcare facilities are necessary for the implementation of ECE (22). However, there may be a discrepancy between the intended and actual implementation of early clinical exposure in healthcare education due to several difficulties in its execution. The following are a few typical causes of this gap:

Figure 1: Challenges in implementing Early Clinical Exposure (22) (23)

1.2.1 Integration of Augmented Reality in Early Clinical Exposure for Medical and Allied Health Students

To fill the implementation gaps of ECE in healthcare education- Immersive, and interactive technology can be integrated to improve the learning experience. Simulation-based learning, telemedicine platforms, and mobile learning apps offer access to realistic scenarios, personalized feedback, and collaborative learning opportunities (24). Augmented Reality (AR) can enhance ECE by superimposing digital data over the real world, which allows realistic simulations, interactive models, and virtual patient interactions, to improve early clinical exposure. AR successfully prepares students for clinical practice by encouraging critical thinking, improving realism, and providing accessibility (25). AR allows students to participate in practical activities like virtual surgery and clinical procedures by superimposing digital material over the actual environment (26). Mobile applications improve accessibility and convenience while promoting active engagement and skill development. AR is a useful tool in healthcare education because it efficiently prepares students for real-world clinical practice and fosters critical thinking by seamlessly fusing digital knowledge with the actual environment (27).

2. Review of past work related to the use of Augmented Reality in Healthcare Education

The article highlighted the developmental and implementation process of a mobile-based AR laboratory for teaching anatomy and physiology in medical and health sciences programs. The traditional labs utilize face-to-face learning using physical models with online alternatives. This does not provide an adequate level of interactive learning. Thus, the integration of AR can help bridge this gap. A smartphone-based AR application was developed using Unity 3D and C# coding which helped in the interaction of 3D models during online sessions. The results showed that AR sessions were more engaging and effective as compared to traditional methods. There were also few issues which were found in the study such as internet connectivity and equipment limitations. The study concluded that AR needs guidelines for proper implementation (29).

Hossain et al (2021) presented a study focusing on the development of a mobile-based AR application that

aimed to enhance the learning experience of medical students for teaching AR bones. A markerless AR application was developed to visualize the bones in 3D via a smartphone. Medical students usually faced issues with the traditional methods like the 2D textbooks, high costs, and limited access to human skeletons. The AR app-enabled interactive learning along with audio-video aids. The study concluded that the AR Bones app was accessible and effective for anatomy education in low-resource settings. The study highlighted further need for app validation for its effectiveness in improving long-term retention of knowledge and improving its ability for complex structures in the future (30).

Experimental and comparative research by Fernandes et al (2020) focused on the use of a mobile-based AR application (NitLabEduca) to teach spinal cord anatomy. 80 neuroscience students, were divided into two groups, one having prior knowledge and the other with no knowledge. One group was taught using traditional printed material followed by AR and the other group was taught using reverse steps. The effectiveness of the AR application was assessed through SUS to evaluate the learning and usability impact of the app. The results highlighted that the app had a significant positive effect on learning outcomes for those who used the app before the printed material. Thus, the app proved to be beneficial but at the same time highlighted the need for research to understand the effect on long-term learning retention of the same (31).

A quasi-experimental design study by Gonzalez et al (2020) highlighted the use of AR for teaching cardiac physiology to biomedical students. A total of 101 students participated in this study. It involved two groups. An experimental group of 58 students used AR for learning and 43 students were taught using traditional lecture-based activities. Students were made to draw and label cardiac structures before and after the intervention. The complexity of drawing anatomy, physiology, and molecular aspects of heart function was assessed. Results highlighted that student who used AR showed a significant improvement in their performance than the students with conventional method teaching. However, the study identified a gap in the impact of AR on the cognitive mechanism and thus further studies should be explored (32).

Another study compared the effectiveness of Magic Mirror with Anatomage and radiological atlases. The study concluded that Magic Mirror has effective results as compared to Anatomage and radiology atlases. Magic Mirror is a great tool to be utilized along with conventional methods of teaching human anatomy (33).

An experimental study was conducted by Yamada et al (2019) The study developed an AR learning system to teach Extracorporeal Circulation (ECC) to Perfusion Technology students. An AR-based ECC system was developed for teaching the students. The system has proved to be beneficial for learning complex concepts for students. The AR module was easy to construct and students found it beneficial (34).

In 2019, Alismail et al did a randomized control trial where AR technology was used to teach healthcare providers with BLS certification about endotracheal intubation. The study explained the AR technology used in teaching the lifesaving skill of intubation. The participants were randomly divided into 2 groups and one group was trained with AR and the other was trained without AR method. Post-training questionnaires were filled which highlighted that the AR group had adhered to the checklist in a better way than the non-AR group. Thus, AR can be used in simulation setup to teach skills, procedures, and equipment that are in risky environments like OT (35).

The study by Weng et al (2018) has described the development of AR mobile support systems to enhance the efficiency of educational methods in clinical scenarios by AR integration. The developed system was tested for usability by 26 participants and was found to be useful, easy to use, good learnability, and reliability. Overall, there was acceptance and satisfaction from the users. The study had a limited scope as only usability was focused and not on the long-term outcomes or wider application of AR in varied scenarios (36).

A study by Jain Nishant et al (2017) described the development and evaluation of a prototype for learning spatial anatomy. The study included the generation of 3D anatomical models from CT scan images and making a system that integrates these into a mobile interface using the Unity 3D engine. This system enables the user to interact with the 3D anatomical models in real time. The higher correlation (R^2= 0.9978) indicates that the tool was proven to accurately render 3D objects when compared to dimensions of physical and virtual objects. There were slight distortions and reliable spatial representation. The study concluded that AR is a user-friendly solution for teaching anatomy and provides accessibility and flexibility across various contents. However, it also highlighted the need for further research to assess the performance of tools with more complex structures and their impact on students' learning outcomes (37).

A Randomized Controlled Trial was conducted by Noll et al (2017) to assess the effectiveness of mobile augmented reality (mAR) as a feature for self-oriented, blended learning in enhancing the learning experiences of students. A total of 44 third-year medical students participated and they were divided into two groups for intervention. The first group was taught using mAR and the other group used a similar app without AR features. The baseline knowledge and emotional status of the participants were assessed by responses to

the questionnaire before and after the intervention. The results showed that there was no significant difference in the immediate learning outcome but mAR group showed better knowledge retention after 14 days. The study highlighted the need for more extensive studies to understand the long-term effect of mAR on learning outcomes (38).

Kucuk et al (2016) conducted a mixed-method study focusing on the "effect of the mobile augmented reality (mAR- MagicBook) for neuroanatomy on learning achievement and cognitive load". 70 Students (34 in the experimental group and 36 in the control group) participated in the study. The result shows that students who learned via the mAR application were more satisfied, academically more successful, and had less cognitive load. Thus, mAR technology can prove to be very helpful in other areas of medical curriculum too (39).

Zhu et al (2015) did a conceptual framework analysis on the use of AR in healthcare education. This study explains "the framework to design, development and application of mobile AR education in healthcare". The framework was developed for the use and training of antibiotics by General Physicians. The framework was developed, focusing on areas like learning outcomes, knowledge level, competence level, action level, etc (40).

Torregrosa et al (2015) conducted a mixed-method study wherein, the researchers developed an ARBook for learning anatomy. The ARBook proved to be more interesting, and motivational and students who were trained with it scored better marks than those who learned through conventional methods (41).

Albrecht et al (2013) conducted a randomized control pilot trial for medical students. A self-developed mAR blended learning environment (mARble) was developed for forensic medicine subjects. 10 students were involved in this pilot study. Previous knowledge about forensic medicine and emotional status were determined. They were randomly divided in two groups (the first group taught with pre-installed mARble. The mARble group performed better in learning efficiency (42).

Thus, when used for medical training, mobile augmented reality (AR) has several advantages, such as the capacity to be implemented in a professional work environment, simulating relevant elements of real-life tasks, offering immediate student feedback, while not always needing a trained professional or trainer to monitor trainee performance. It is noteworthy to see that some areas of AR in medicine have already incorporated it into routine practice.

3. Discussion

The study highlighted that the number of studies focusing on the role of mobile-based AR for clinical training of medical and allied students is comparatively less. A majority of the studies that were reviewed, compared the use of AR with other teaching tools and demonstrated that AR had positive outcomes and addressed several key challenges faced by traditional teaching methods (42)(39). The included studies consistently showed that AR can enhance and simplify students' understanding of difficult concepts by providing immersive and interactive experiences (38)(29). AR has helped in facilitating the acquisition of skills, mainly in the areas where hands-on clinical practice is limited or where students have accessibility issues to a variety of patient cases (46). Further, AR has also proven to be beneficial in boosting motivation and confidence due to the ease for students to practice independently and repeatedly without risking real patient or self (40)(14). The reduced cognitive load and increased motivation reported in several studies have helped students be more confident and master specific skills more quickly (47).

While this review highlighted the advantages offered by AR, it also emphasized that AR cannot completely replace traditional hands-on training. It is difficult to completely replicate the real-world complexity and unpredictability of patients and clinical scenarios in a virtual environment (48). Thus, AR can be considered as an additive tool rather than a sole solution. This is supported by studies in the literature which showed improvement in short-term learning outcomes (31)(32). Several significant gaps were identified in the literature through this review. There is a lack of research examining the long-term effectiveness and impact of AR on clinical competencies and professional practices of patient care (31)(40)(32)(36). Majority of the studies were study on a small sample size and in developed nations. This makes it difficult to generalize the findings of the studies, thus the need for longitudinal data. Another major gap found in this review was the limited studies and pieces of evidence on the cost-effectiveness of the AR interventions, mainly in low-resource settings (49). The high costs involved in designing, developing, implementing, and maintenance of AR technology is a hurdle for its adoption at a larger scale, mainly in low- and middle-income countries. There is also a need for standardized guidelines and protocols for convenient integration of AR into medical and allied health curriculum (35)(50)(51). More studies are required to understand the extent and possibilities to which AR can be used in varied areas of practical and clinical education.

The strength of this review is that the studies included were of varied designs and methodologies. Some weakness included that the samples size for experimental studies were small with short term follow-up duration and self-reported outcomes. This can contribute in potential biases. The simulated environment makes it difficult to fully understand the challenges of real-clinical environment. As majority of the studies did not focus on long term outcomes, our knowledge on retention of clinical skills for a loner time and its impact on patient care remains blur.

4. Conclusion

In this review Augmented Reality (AR) is described in detail. AR technology has been widely used in recent years, mainly in education. The use of AR in the medical field (both for clinical and theoretical teaching) is proving beneficial. AR is an advanced technology that can help enhance early clinical exposure of medical and allied health education. This technology enhances the educational experience by creating a secure atmosphere and fostering the development of particular professional skills. The study material prepared using AR technology and mainly mobile AR is easy to understand, more immersive, interesting, and easier to understand. It also has the advantage of flexibility and accessibility. Thus, AR can be considered as an additive tool to current teaching aids. However, there are significant gaps and challenges such as cost-effectiveness, lack of evidence on long-term effects on learning outcomes, lack of standardized guidelines and protocols that exist which need to be addressed to integrate AR smoothly into the existing curriculum. Addressing the identified gaps by doing more research can help in upgrading and modernizing medical and allied health education as well as have efficient, skilled, and more confident future healthcare professionals.

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