REVIEW ARTICLE

Nursing and Medical Health Science Education: A Mini-Review on Recent Updates of Augmented Reality (AR) And Virtual Reality (VR) Applications

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ABSTRACT

The technologies of virtual reality (VR) and augmented reality (AR), conjointly known as extended reality (XR) digitally alter the perception of reality. An XR environment can help learners suspend disbelief and encourage active engagement with the simulation activity by fully submerging them in a very realistic artificial setting. The incorporation and applications of AR and VR in healthcare simulation offer numerous benefits beyond enhancing and improving students' learning experiences in nursing and medical health sciences education. However, despite the ascertained numerous advantages of AR and VR, there are concealed disadvantages. This review provides recent updates on AR and VR technologies available in nursing and medical health sciences teaching and learning which will provide an invaluable perspective that will benefit students and educators within these specialties. In this review, we aim to discuss the current applications, advantages and disadvantages of AR and VR applications in nursing and medical health sciences education.

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Keywords: virtual reality (VR), augmented reality (AR), applications, nursing and medical health sciences, students' learning experiences.

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INTRODUCTION

Virtual reality (VR) and augmented reality (AR), collectively known as Extended Reality (XR), are technologies that digitally alter the perception of reality. A VR environment immerses the learner completely within an artificial setting that is highly realistic, which can suspend disbelief and promote active engagement with the simulation activity (1). Conversely, AR enhances the learner's perception of the real world by superimposing digital images onto the real environment (2).

VR and AR have been utilized in the process of teaching and learning (T&L) for the past decade. These technologies are very beneficial, especially in fostering genuine interest and encouraging students to be involved in interactive learning thus enhancing active participation in T&L (3). The benefit of AR and VR applications in T&L can be achieved via either traditional method of face-to-face (FTF) or online methods that have been extensively explored since the pandemic era of coronavirus disease 2019 (COVID-19) (4).

The students' target populations that can benefit from AR and VR are vast, especially in higher education which includes medical and dentistry students (5). Although very promising, VR and AR should be used as a supplemental resource or teaching aid but not as a complete replacement for online and traditional learning methods for these students. Not limited to preclinical medical and dental students, nursing and medical health sciences students also benefited tremendously from these VR and AR applications (6, 7).

Medical health sciences can be defined as the applied science and fundamental study of health and medical care that is associated with human physical and behavioural well-being. They encompass multiple academic disciplines with a variety of sub-disciplines and skills including medicine, nursing, pharmacy, physical therapy, dental hygiene, nutrition, communication sciences and disorders, speech and hearing sciences or general health sciences and emerging patient safety disciplines such as social care research.

This review provides recent updates on AR and VR technologies available in nursing and medical health sciences T&L which will provide insight that will benefit students and educators within these specialities. In this review, we aim to discuss the current applications, advantages and disadvantages of AR and VR applications in nursing and medical health sciences education.

CURRENT APPLICATIONS OF AR AND VR IN NURSING AND MEDICAL HEALTH SCIENCES EDUCATION

Both AR and VR technologies are increasingly popular in healthcare, particularly in healthcare simulation. The advancement of these technologies has enabled their use as simulation modalities, providing more engaging learning experiences. There is a growing use of AR and VR in healthcare simulation for nursing and health sciences in both Western and Asian regions. This section will discuss the usage and application of AR and VR in these two areas.

Both AR and VR have distinct sets of hardware and software. AR hardware and software are utilized to overlay digital images onto the real world, while VR hardware and software create entirely virtual environments without interacting with the real world. In Asian and Western countries, there is a mixed usage of global and locally developed software development kits (SDK) for AR and VR (Table I). Examples of Western local SDKs are ARSim2care and VR4 Health, while the Asian local SDK is Pvix VR (8-10). Additionally, Unity is a globally used software in Asian and Western countries (6, 11).

Regarding hardware usage, Western countries use more high-end hardware such as Microsoft HoloLens and Oculus Quest 2 (6, 8, 12). In contrast, Asian countries prefer more cost-effective and flexible hardware such as Android or iOS handheld devices and optical portable wearable devices (11). From the above description, it is evident that both regions use a mix of global and local SDKs with a preference for flexibility in Asian usage. This indicates that SDK usage depends on regional preference and may also depend on the developmental capabilities of the region. Additionally, in terms of hardware usage preference, Western countries prefer to use high-end hardware, whereas their Asian counterparts prefer more cost-effective and flexible software. These differences may suggest variations in resource allocations and needs.

The current aim of studies involving AR and VR focuses on learners' reactions and learning levels in both Asian and Western countries. Key elements for learners' reactions reported in the studies are related to their response to learning and their use of technology (6, 12) (Figure 1 and Figure 2). Both regions show similar emphasis on learners' satisfaction, motivation to learn, confidence and level of engagement. The experience has been found to motivate participants to learn, promote active learning and encourage autonomous work (8, 13). Furthermore, it provides a realistic, interactive and immersive learning experience (12). Additionally, the technology enhances the clarity and relevance of the educational content (8, 13). It also provides a safe learning environment and the freedom to learn from mistakes (12). Western studies are also interested in looking at the aspects of technology acceptance and ease of use. Despite the generally positive reports on the use of technology, some studies have noted adverse effects, such as dizziness, associated with the use of AR (14).

The studies show a similar emphasis on knowledge acquisition in Asian and Western countries. The primary areas of focus for knowledge acquisition include basic knowledge of anatomy, physiology and pathophysiology, as well as applied clinical knowledge and clinical reasoning (14-16). Additionally, there is a similar emphasis on skill acquisition, particularly in learning the procedural steps. The studies also examine the impact on learners' attitudes towards their clinical skills and practices. A study designed an obstetric VR simulation activity that allows learners to change their roles as healthcare practitioners or patients to explore how the experience inspires empathy in learners (11). Furthermore, Ɓlvarez-Nieto et al. reported that the AR environmental health simulation activity enabled students to understand the link between different domains of the subject, leading to a change in attitude (17). Lin et al. also reported that students gain more confidence in performing procedures in clinical settings (10).

Table I: Augmented reality (AR) and virtual reality (VR) applications in teaching and learning nursing and medical health sciences students

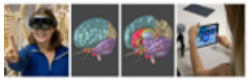
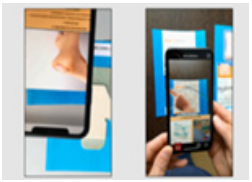
	Reference article	Country	Target populations	Application usage	AR or VR Software and Hardware	Mechanisms	Pictures
1.	(Moro et al. 2021)	Australia	Health Science Students	Learn anatomy and physiology of the brain	**AR** **Software** **Unity 3D:** Development platform **3D Studio Max:** 3D modelling software **Vuforia v5 plug-in for Unity:** Enables AR visualisation using the device's camera. **Visual Studio v2019:** Used for exporting Unity 3D files for HoloLens. **Hardware** **Mobile AR**: Visualised on Samsung Galaxy Tab S3 tablets **HoloLens:** Unity 3D files exported for use with HoloLens through Visual Studio.	**Mobile-Based AR:** Start the application on a mobile device and hold a marker to display a 3D brain model. Rotate the brain model by moving the marker and tapping on features to highlight and label them. Click "dissect" to remove and view the underlying anatomy. Play a 6-minute audio narration to highlight relevant brain areas in different colours. **HoloLens-Based AR:** Content, narration, and modelling are identical to the mobile device, with the brain presented as a hologram. Use voice or gesture commands to highlight, label, and dissect features. Interactions are detected by HoloLens for seamless interaction.	
2.	(Rodríguez-Abad et al. 2022)	Spain	Nursing Students	Leg ulcer care	**AR** **Software:** **HP Reveal:** User-friendly mobile app for creating and viewing AR experiences. **Aumentary creator**: Desktop tool for designing and publishing advanced AR content, including 3D models and videos.	The study compared traditional learning methods with AR-enhanced methods across four stations on wound care. Control groups used traditional paper notes and printed materials, while experimental groups accessed digital content via QR codes and AR triggers. AR content included multimedia presentations, images, videos, animations, and 3D models. The experimental groups used real objects (e.g., wound dressings, compression bandages) as triggers for AR content, which provided a more interactive and immersive learning experience than traditional methods.	
3.	(Álvarez-Nieto et al. 2022)	Spain	Nursing Students	Environmental Health	**AR** **Software** **MOZAIK education®, Sketchfab®, Biodigital®, and MERGE®:** these apps provide the digital content and access to it. **Hardware** **Tablets and mobile phones:** Access **A**R content, **MERGE Cubes and QR codes:** Markers to activate digital content when scanned.	**AR Integration:** Students are immersed in clinical scenarios with realistic visualizations. Linked digital content (3D images and videos) enhances the learning experience. **Activation:** QR codes and MERGE cubes are used as markers to trigger digital content. Students access augmented reality content using tablets or mobile phones.	

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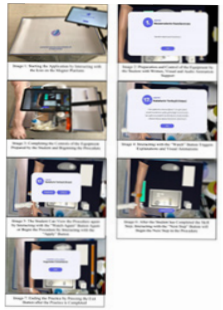
Table I: Augmented reality (AR) and virtual reality (VR) applications in teaching and learning nursing and medical health sciences students (CONT.)

	Reference article	Country	Target populations	Application usage	AR or VR Software and Hardware	Mechanisms	Pictures
4.	(Escalada-Hernandez et al. 2024)	Spain	Nursing Students	Procedural skills (intramuscular injection, nasogastric tube insertion, endotracheal intubation, suctioning via tracheostomy tube)	**AR** **Software** **ARSim-2care:** an application that enhances procedural training on a specific model of manikin by visualising internal anatomical structure in real-time. **Hardware** **Microsoft Hololense Head-mounted display (HMD)** to visualise and interact with the virtual anatomical model.	The ARSim2care application, used with HoloLens smart glasses, features a home screen with icons for procedures like intramuscular injection and nasogastric tube insertion. Users select a procedure and access detailed instructions via voice commands. The app offers automatic (shape recognition) and manual modes for visualising and adjusting internal structures.	 
5.	(Avci and Kilic 2024)	Turkiye	Nursing Students	Intravenous catheter placement	AR Not mention	The setup involved a magnetic platform on a training table with equipment arranged in specific locations and a tablet positioned for optimal viewing. Students started the AR application using a pedal button, which displayed the practice table on the tablet. The tablet showed 3D virtual depictions of the equipment, and students used virtual versions to perform interventions on a model organ. Steps were shown repeatedly, allowing students to progress at their own pace with no time limits. The procedure provided an interactive and flexible learning experience.	
6.	(Veer, Phelps, and Moro 2022)	Australia	Health Science Students	Learn the anatomy of the lungs, physiology, pathology and pharmacology related to asthma	**Mixed Reality** **Software** **Cinema 4D v21:** For creating and editing the 3D model, **Unity 3D:** For developing the mixed reality application, **Visual Studio v2019:** For exporting the application. **Hardware** **Microsoft Hololennse HMD**	The 3D model is visible in front of the user, with hand gestures and voice commands allowing interactivity, while the lesson plays as an audio stream through the headphones.	
7.	(Fairén, Moyés, and Insa 2020)	Spain	Health Science Students	Learn the anatomy of human organs	**VR** **Software** VR4Healths. **Hardware** HMD device.	**VR4Health:** A VR application for HMD devices providing an immersive, self-learning tool with labelled virtual anatomical models, visual and sound feedback, and multi-language support. Users can navigate, inspect, and dissect anatomical structures, with interactions recorded for teacher review. The application is scalable, allowing model additions or modifications based on teacher suggestions.	

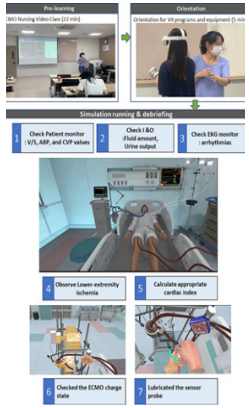
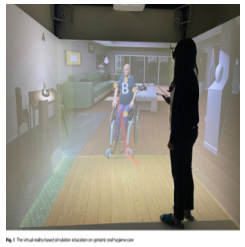
CONTINUE

Table I: Augmented reality (AR) and virtual reality (VR) applications in teaching and learning nursing and medical health sciences students (CONT.)

	Reference article	Country	Target populations	Application usage	AR or VR Software and Hardware	Mechanisms	Pictures
8.	(Pao Ju Chen and Wei Kai Liou 2022)	Taiwan	Nursing Students	Communication (obstetric condition)	**VR** **Software:** Google VR SDK, Unity, Video editing software. **Hardware:** Low-cost VR headset, Android/ iOS devices, 4K HD 360° camera, ordinary mobile phones.	The study developed an interactive obstetrical nursing VR app for low-cost VR headsets, compatible with Android and iOS devices using Google VR SDK and Unity. The lesson content was filmed with a 4K HD 360° camera and edited into 360° panoramic images for clinical use. Students use their mobile phones with a 3D VR headset to experience the app, choosing either the nurse's or the mother's perspective. Navigation is done using the eye centre dot and handheld device buttons. Students can switch roles, return to the main menu, and select new lessons or perspectives at any time.	 Fig. 2: Students put on VR headsets and enter the immersive virtual environment  Fig. 3: Conducting the exercise from the first-person perspective of a nurse  Fig. 4: Conducting the exercise from the first-person perspective of a woman in labour
9.	(Plotzky et al. 2023)	Germany	Nursing Students	Endotracheal suction skills	**VR** **VRlow:** Input via controllers, tracking via head and controllers. **VRhigh:** Input via hand gestures, tracking via head and hands. **Head-mounted Display:** Oculus Quest 2 ™.	Students actively perform endotracheal suctioning on virtual patients in a virtual hospital room. They will be guided by audio instructions and visual hints. The procedure should be conducted in a sterile manner; green dots on the patient represent microorganisms, which serve as feedback to students.	
10.	(Kiegaldie and Shaw 2023)	Australia	Nursing Students	Management of common clinical conditions (Verbally aggressive patient, deteriorating patient, cognitive impairment, palliative and end-of-life care)	**VR** **Software:** **VirtualU** (VR software application), **Jasper-VR** handbook as a guide. **Hardware:** **VR headset, mobile phones, Education institute's Wi-Fi** (for downloading the application).	The study used JasperVR's VirtualU platform to train students on clinical scenarios with 360-degree video and sound technology. Students interacted with simulated participants, making choices that impacted patient outcomes, with feedback provided through visualized pathways. The VR intervention included free-roam and mastery video options. Students received VR headsets and JasperVR handbooks, downloaded the VirtualU software onto their mobile phones using the institute's Wi-Fi, and received technical assistance. In Free Roam Mode, students navigated scenarios, made clinical decisions, and reviewed them both inside and outside classroom time. The program also featured Mastery Videos from clinical experts to aid in preparation for clinical placements, with teachers using these videos to highlight high-quality performance.	

CONTINUE

Table I: Augmented reality (AR) and virtual reality (VR) applications in teaching and learning nursing and medical health sciences students (CONT.)

	Reference article	Country	Target populations	Application usage	AR or VR Software and Hardware	Mechanisms	Pictures
11.	(Mäkinen et al. 2023)	Finland	Nursing Students	Clinical reasoning skills in resuscitation scenarios.	**VR** **Software:** **Unity3D** (a development platform for creating the VR environment). **Hardware:** **HTC VivePro system** (VR headset).	The VR simulation utilised the HTC VivePro system to immerse nursing students in a 3D environment, enhancing their clinical reasoning skills in resuscitation scenarios. Developed using Unity3D, the simulation guided students through the clinical reasoning process, using multiple-choice menus for actions and providing immediate feedback after each decision. Players assumed the role of a nurse, assessing critically ill patients with the ABCDE approach while ensuring psychological safety with a researcher present and the option to stop the session at any time.	
12.	(Lee et al. 2024)	South Korea	Nursing Students	Nursing care in extracorporeal membrane oxygenation (ECMO) for critically ill patients	**VR** **Oculus HMD** and controllers	Students perform various nursing interventions on virtual ICU patients in a virtual ICU. Students use HMDs and controllers to interact with the virtual environment.	
13.	(Lin et al. 2024)	Taiwan	Nursing Students	Geriatric oral healthcare	**VR** **Software:** Pvix VR (virtual interactive software). **Hardware:** Optical portable wearable device, 3D glasses with remote control, VR headset.	Participants used Pvix VR software with 3D glasses, a remote control, and a VR headset. They spent 5 minutes familiarizing themselves with the equipment before engaging in a 30-minute VR-based simulation training session in an oral skills training room. The training included selecting actions with the remote control, guided by speech and text instructions, and interacting with a virtual scene of an elderly man with dental issues. The training began with an explanation of older adults' physical and oral health, and participants were evaluated on their competencies in geriatric oral health care.	

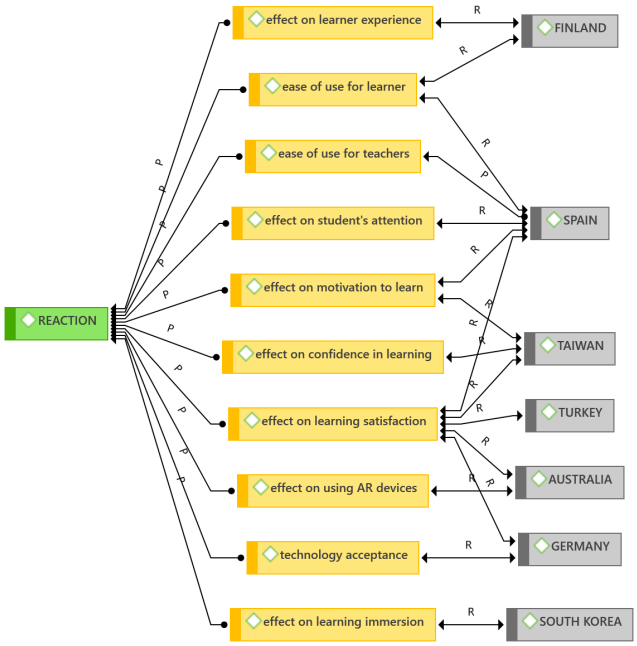


Figure 1: Learner's Reaction (P: a property of, R: associated with)

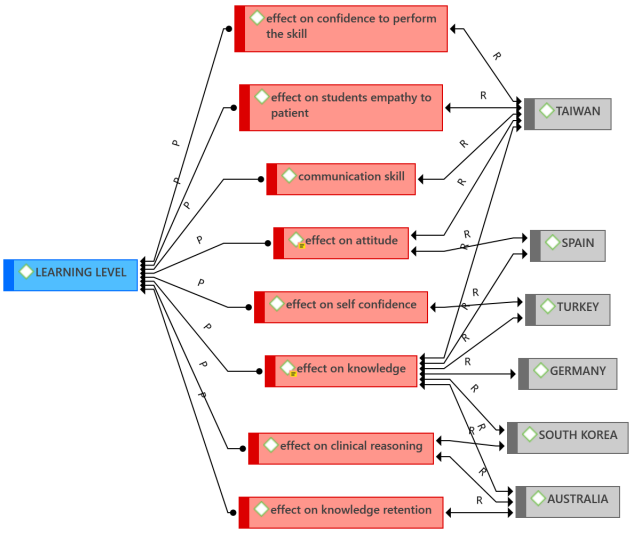


Figure 2: Learning Level (P: a property of, R: associated with)

In summary, the integration of AR and VR in healthcare simulation has significantly enhanced the learning experience for students in Asian and Western countries. Studies in both regions show similar emphasis on learners' reactions and the level of learning, focusing on key areas such as learning satisfaction, engagement and technology acceptance (Figure 1 and Figure 2). Additionally, research related to learning level includes knowledge acquisition, skill acquisition and affective domain development. There are regional variations in preference regarding the use of AR and VR in T&L, which may be related to differences in needs and resource allocation. Overall, the use of AR and VR in nursing and health science education is gaining significant interest, indicating promising growth and expansion in this field.

ADVANTAGES OF USING AR AND VR IN NURSING AND MEDICAL HEALTH SCIENCES EDUCATION

In recent years, AR and VR technologies have become increasingly popular in the education and training sectors for their effectiveness in enriching the learning experience. By offering immersive and interactive learning environments, AR and VR sparked a fundamental transformation in the field of medical education and training. There are many advantages of using AR and VR in T&L nursing and medical health sciences which most importantly include improving students' learning experience and effectiveness.

Improving Students' Learning Experience

Advancing nursing students' theoretical knowledge and practical proficiencies

Over the past five years, there has been a growing emphasis on enhancing the learning experience and effectiveness of nursing students. One key area of focus has been advancing students' theoretical knowledge and practice proficiencies to prepare them for real-world clinical settings.

Recent studies have shown that incorporating innovative teaching methods can significantly improve nursing students' understanding of complex medical concepts and their ability to apply this knowledge in practical scenarios. Narnaware and Neumeier et al. discovered that the use of an interactive three-dimensional (3D) virtual human cadaver helped nursing students grasp more human anatomy knowledge, leading to higher exam scores and overall grade point average (GPA). Therefore enhancing long-term knowledge retention compared to traditional lecture-based instruction and serving as an effective alternative to cadaveric dissection in nursing programs (7).

Similarly, a study demonstrated that both the immersive 3D interactive video program and a traditional demonstration video effectively enhanced nursing students' knowledge and confidence in performing nasogastric tube feeding (18). While there were no significant differences in outcomes between the two groups, participants in the intervention group reported higher satisfaction with the immersive video program. The results suggest that immersive and interactive learning methods, such as VR technology, could be valuable tools for improving nursing skill acquisition, thus, enhancing their clinical skills proficiency and decision-making abilities.

Enhancing critical thinking and clinical decision-making skills

In addition to strengthening theoretical knowledge and practical skills, nursing education has also placed

a greater emphasis on developing students' critical thinking and clinical reasoning abilities. This is crucial for ensuring that future nurses can effectively assess patient conditions, make informed decisions, and provide high-quality care.

A 2020 study reported that the integration of case-based learning and peer-led debriefing methods significantly improved students' critical thinking skills in clinical performance competency. Students who participated in these activities demonstrated better self-directed learning and improved clinical competencies (19).

A systematic review investigates the usability of AR in higher education for health sciences (20). It describes the types of interventions developed, their impacts on various psycho-pedagogical aspects of students; and the advantages, disadvantages and challenges of incorporating AR in the T&L process. The review highlights the diverse applications of AR in health sciences education. AR interventions improved skill acquisition, motivation, satisfaction, and autonomous learning, especially in courses requiring three-dimensional visualization. These immersive learning environments allow students to practice responding to complex, real-life scenarios in a safe and controlled setting, better preparing them for the challenges they will face in their future careers.

Improving learning accessibility and engagement

The COVID-19 pandemic has accelerated the adoption of online and hybrid learning models, which has presented both challenges and opportunities for enhancing the student experience. Another key focus in nursing education has been improving learning accessibility and student engagement.

A previous study evaluates the effectiveness of different types of blended learning methodologies in nursing education, particularly those integrating automated feedback and hypermedia resources (21). The study demonstrated that those blended learning methodologies enhance learning outcomes by providing continuous access to learning materials, facilitating personalized learning, and improving practical skills through problem-based learning.

Moreover, the integration of gamification has been shown to enhance nursing students' motivation and active participation in the learning process. Kowitlawakul et al. reported that the integration of educational technology in nursing education is highly beneficial. It enhances student engagement and motivation, therefore improving academic performance and leading to better academic outcomes (22).

ADVANTAGES OTHER THAN OF STUDENT'S LEARNING EXPERIENCE AND EFFECTIVENESS

Apart from enhancing students' learning experience, using AR and VR in nursing and health sciences education offers several additional advantages including the development of competencies for professional practice, remote and flexible learning opportunities, interprofessional education by collaborative learning from diverse healthcare fields and cost-effectiveness and support for research and innovation in healthcare education.

Development of competencies for professional practice

Firstly, simulation fosters the development of competencies for professional practice including realistic simulation and enhanced safety. AR and VR allow students to practice in realistic simulated environments that mimic actual clinical settings. This helps in developing practical skills and familiarity with procedures without the risks associated with real patients (23). This realism helps students experience scenarios that closely resemble actual clinical settings, including hospital rooms, operating theatres, and patient care units. Besides that, simulations provide a safe space for students to practice and hone their skills without the pressure or risks associated with real patients. This reduces anxiety and allows learners to make mistakes and learn from them without consequences for patient safety. Students can learn and make mistakes in a controlled virtual environment, promoting safer learning experiences. They can practice handling emergencies and challenging situations without compromising patient safety (23).

Remote and flexible learning opportunities

AR and VR offer the advantage of remote and flexible learning opportunities, enabling learners to access training materials and simulations from any location globally. This capability is especially valuable in situations where learners cannot participate in traditional in-person training sessions. For instance, research conducted at the University of Southern California demonstrated that VR training effectively instructed surgeons, even when they were geographically dispersed (24).

Interprofessional education by collaborative learning from diverse healthcare fields

Additionally, AR and VR offer benefits in interprofessional education by fostering collaborative learning among students from diverse healthcare fields. These technologies enable simulations of interdisciplinary team interactions, enhancing crucial skills in communication

and teamwork necessary for healthcare environments. They also support personalized learning paths tailored to individual learning styles and speeds, allowing students to revisit challenging concepts or procedures as required (25).

Cost-effectiveness and support for research and innovation in healthcare education

Moreover, AR and VR demonstrate cost-effectiveness in healthcare education. Although the initial setup costs can be substantial, these technologies have the potential to decrease training expenses typically linked with traditional methods, such as the procurement of medical supplies and equipment (26). Furthermore, AR and VR drive innovation in healthcare education by encouraging the exploration of new treatments, procedures, and technologies. They provide platforms for testing innovative ideas and protocols in a controlled environment before implementing them in clinical practice. An example of this innovative approach involves utilizing multi-user VR to immerse participants in an underwater environment with jellyfish and a growing glass sponge. This scenario facilitates synchronized breathing and heightened awareness. Each participant's breath is metaphorically represented by a jellyfish, providing clear visual feedback. As participants synchronize their breathing, the glass sponge grows and emits light. This innovative design emphasizes creative interactivity and highlights the potential to enhance awareness and control of breathing through engaging and diverse methodologies (27).

In summary, AR and VR offer numerous benefits beyond enhancing students' learning experiences in nursing and medical health sciences, including improving students' learning experience and effectiveness, the development of competencies for professional practice, remote and flexible learning opportunities, interprofessional education by collaborative learning from diverse healthcare fields and cost-effectiveness and support for research and innovation in healthcare education.

DISADVANTAGES OF USING AR AND VR IN NURSING AND MEDICAL HEALTH SCIENCES EDUCATION

Nevertheless, despite the undisputable advantages of AR and VR, there are hidden disadvantages of using AR and VR in nursing and medical health sciences education.

Capabilities and the technical performance of the information technology (IT) environment

The potential and limitations of AR/VR are directly tied to the technical performance and capabilities of the information technology (IT) environment. This is due to its technologies consisting of various interacting components, including computational devices, operating software, registration techniques, and tracking sensors (28). Unlike VR, AR overlays additional information onto physical reality, making it more advantageous for practical applications. This capability allows AR to provide an enhanced 'see-through' experience in practical operations (29).

Management of equipment, hardware and data security

Several uncertainties currently limit the widespread use of AR/VR technologies in clinical routines. Technical barriers such as equipment and hardware impose challenges as most image-guided interventions necessitate multiple complex pieces of equipment and often require a few personnel to manage different aspects of the procedure in a confined workspace (30). Additionally, the increasing amount of data needs to be managed wisely. Most of these uncertainties are expected to be resolved with ongoing advancements in IT. While data anonymization is essential, there are challenges with the potential re-identification of individuals.

The actions of vulnerable users and organizations can jeopardize an entire system, increasing the risk of cybercrimes (31). Due to the reliance on information and communication technology (ICT), cybersecurity challenges like cyber-attacks and information leaks might happen. Losing control of these systems can negatively affect quality of life, security, privacy, the economy, and technology, putting people at risk.

Limitations of technology resources to enhance AR VR Realistic AR VR requires high-resolution images, quality of sound, haptic input and feedback devices and high processing power. There is a risk that the skills and movements learned will be unsuitable for real-life situations. Additionally, the structures of the organs and tissues must be highly accurate, and any changes in their shape, size, or angle must precisely match the user's movements and interactions.

The benefit of cost-efficacy versus operator-dependent versatility on AR VR technologies

Cost-benefit analysis from both clinicians' and patients' perspectives, given that AR/VR applications remain costly for everyday use. Significant initial investment for technology setup, technical complexities that may cause user experience issues, and the challenge of limited content and customization options. Users might also face a learning curve, and ethical concerns regarding patient acceptance and privacy may arise. A study by Chou et al, in comparing between Simbionix UROMentor virtual-reality simulator (VRS) and training model for basic ureteroscopy training found that VR trainers are significantly more expensive than bench models but provide much greater versatility (32).

Cybersickness

Cybersickness in VR stems from both hardware and software issues, creating a major challenge. Hardware issues like latency, the delay between a user's action and the corresponding change in the virtual environment, can be extremely disorienting (33). Cybersickness, characterized by nausea, disorientation, and oculomotor issues, is a notable concern. It differs from simulator sickness, which has distinct features. Unlike motion sickness, which results from physical movement, cybersickness primarily stems from visual cues in VR and is marked by heightened discomfort, especially nausea and disorientation. In VR environments, conflicting cues often lead to sensory dissonance, triggering cybersickness. This conflict can be attributed to vection, an illusion of motion (34). Vection, especially when coupled with movements like linear and angular accelerations, is a significant cause of cybersickness in VR. Moreover, cybersickness can severely hinder cognitive and motor functions, which are essential in VR applications for education, research, and training. As VR becomes more prevalent in technology, the need to understand and reduce cybersickness remains a critical issue.

CONCLUSIONS

In conclusion, the integration of AR and VR has significantly enhanced the learning experience for higher education students in Asian and Western countries. The use of AR and VR as a supplementary learning aid in nursing and health science education is gaining significant interest, indicating promising growth and limitless expansion in this field. AR and VR offer numerous benefits beyond enhancing students' learning experiences in nursing and medical health sciences, specifically in improving students' learning experience and effectiveness. Despite the undisputable advantages of AR and VR, there are hidden disadvantages of using AR and VR in nursing and medical health sciences education that should be carefully managed.

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