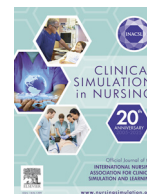




Contents lists available at ScienceDirect

Clinical Simulation in Nursing

journal homepage: www.elsevier.com/locate/ecns

Review Article

Utilization, application and effectiveness of metaverse in simulation-based nursing education: A systematic review

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ARTICLE INFO

Keywords:

Healthcare
Metaverse
Nursing education
Review
Virtual environment
Virtual world

ABSTRACT

Background: The Metaverse is an emerging technological innovation with potential applications for healthcare education.

Aim: The objective of this systematic review was to evaluate the utilization, application, and effectiveness of the Metaverse in simulation-based nursing education.

Methods: A comprehensive search was conducted across eight electronic databases, yielding 32 studies that met the inclusion criteria. The studies, conducted between 2016 and 2023, were predominantly quantitative, with some employing mixed methods and qualitative approaches.

Findings: The review identified two main themes: learning outcomes and learner experiences. Learning outcomes included knowledge acquisition, clinical skill development, self-efficacy, confidence, and motivation. Use of Metaverse components, particularly virtual reality (VR), generally improved knowledge and technical skill acquisition, especially in areas such as infection control and neonatal resuscitation. Gains in nontechnical skills, including problem-solving and critical thinking, were also observed. However, evidence on motivation and confidence was mixed, with some studies reporting significant improvements and others finding no difference compared to traditional teaching methods. Learner experiences encompassed satisfaction, presence and immersion, usability, acceptability, and anxiety reduction. Learner satisfaction was consistently high, with VR perceived as visually appealing, interactive, and conducive to engaging learning environments. VR also enhanced presence and immersion, creating realistic and interactive simulations. Usability was typically rated as good, though challenges such as cybersickness were noted. Overall, participants viewed Metaverse technologies positively for their ability to create immersive, enjoyable, and effective learning experiences.

Conclusions: This review highlights the potential of the Metaverse in nursing education, particularly for enhancing learning outcomes and learner experiences. However, the lack of studies on the full application of the Metaverse, including social connectedness, suggests the need for further research to explore its comprehensive role in simulation-based learning.

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Introduction

The Metaverse, acknowledged as the next phase of internet advancement, represents a dynamic and rapidly expanding technological innovation (Buhalis et al., 2023). Originally described in Stephenson's 1992 film 'Snow Crash' (Au, 2023), the

use of the term has grown since Zuckerberg rebranded Facebook as 'Meta' in 2021 and committed \$US150 million to its development (Meta, 2021). Defined as a three-dimensional virtual realm enabling avatar-mediated interactions free from real-world constraints, the Metaverse serves as a platform for social networks that are primarily focused on sharing or discussing content (De Gagne et al., 2023; Narin, 2021; Park & Kim, 2022b).

The Metaverse can provide opportunities for hybrid learning experiences in continuous, alternative, online 3D virtual environ-

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ments where users are co-owners of the virtual spaces and co-creators of fluid, bespoke curricula (Mystakidis et al., 2021). Currently, there is a paucity of research on the utilization and benefits of the Metaverse for healthcare education. This systematic review therefore aimed to identify and critically appraise contemporary literature on the use, application and evaluation of the Metaverse in nursing education, with a specific focus on simulation-based learning (SBL).

Background

Online education has emerged as a cornerstone of higher education since the mid-1990s (Watts, 2016), but education modalities have rapidly evolved since its inception. This transition has required educators to devise strategies that effectively support learning and enhance student satisfaction within virtual classroom settings (Neuwirth et al., 2021). Both synchronous (real-time interaction via audio or video conferencing) and asynchronous (self-paced, individualized learning) online modalities are commonly used (Gillett-Swan, 2017). Initially, asynchronous learning methods were introduced to provide self-paced and flexible learning experiences (Fabrizz et al., 2021). However, advancements in technology have meant that synchronous online learning has gained prominence as a means to enhance learner engagement (Watts, 2016) through the provision of real-time interactions between students and instructors using audio or video conferencing (Alhazbi & Hasan, 2021).

Both synchronous and asynchronous methods of online learning can present challenges for students and educators. Synchronous learning can give rise to logistical and privacy concerns, along with diminished learner concentration, focus, motivation, and performance (Besser et al., 2022), all of which can impact learning. Asynchronous learning can lead to feelings of isolation as students lack real-time interaction with their instructors and peers, potentially affecting motivation and performance (Lee & Han, 2022). These concerns have led to further investment into technology and its capabilities with the aim of enhancing learner engagement (Timotheou et al., 2023).

Recent technological advancements have seen the introduction of gamification (please see a complete list of definitions used in this paper in Appendix 1) and virtual reality (VR) into the educational domain, with a growing body of research supporting their efficacy (Barteit et al., 2021; Di Natale et al., 2020; Sailer & Homner, 2020; Shorey & Ng, 2021). Gamification entails the incorporation of gaming design elements into nongaming environments (Sailer & Homner, 2020). Specifically in the context of learning, gaming refers to intentionally integrating game elements to adapt and improve conventional learning approaches (Sailer & Homner, 2020). VR technology is a simulated environment that completely immerses users in a computer-generated world, creating a sense of presence and interaction within the virtual environment (Lampropoulos, 2024). These approaches are designed to create immersive, enjoyable, and engaging learning environments and experiences that foster inclusivity and prioritize student-centered learning (Lampropoulos, 2024). Incorporating game-based elements and VR enhances motivation, learning and engagement (Agustini et al., 2023). Currently, gamification provides a reasonably comparable experience to the Metaverse due to its focus on immersive 3D virtual reality (Agustini et al., 2023).

The Metaverse is a dynamic internet application and social platform that intertwines real and virtual realms through innovative technologies (Wang et al., 2023). It incorporates a range of emerging tools: digital twins create mirrored versions of real-world environments; virtual reality (VR) and augmented reality (AR) deliver immersive, three-dimensional experiences; and 5G networks sup-

port the seamless operation of large-scale, interconnected applications (Gim et al., 2022).

Despite growing interest, there is no consensus on a single definition of the Metaverse. It is often described as a socially immersive virtual environment that employs augmented virtual reality (AVR) technology (Narin, 2021). This environment blends virtual and physical elements to establish economic, social, and identity frameworks, enabling users to create content and shape their surroundings (Cieslowski et al., 2023; Narin, 2021). Within this context, the Metaverse can serve as a virtual realm that immerses users in diverse work, educational, and entertainment activities (Garon, 2022).

The Metaverse has also been described in terms of its technological dimensions with interconnected environments involving multiple technology devices such as computers, users and datasets presented in a three-dimensional (3D) space (Chang & Lai, 2021), and where social interactions and communications take precedence (Chang & Lai, 2021). The Metaverse represents a digital realm that connects various virtual worlds, enabling users to participate in social and economic activities securely and without the constraints of the physical world (Cheng et al., 2022; Mozumder et al., 2022; Petrigna & Musumeci, 2022). Therefore, the essence of the Metaverse lies in the removal of physical space, distance, and objects, encompassing 3D gaming platforms such as game consoles, virtual reality headsets and computers (George et al., 2021).

The Metaverse is characterized by a service-oriented approach, delivering content, experiences, and social interactions with an emphasis on sustainability and societal impact (Jans, Lucas, & Levett-Jones, 2023; Park & Kim, 2022b, p. 4210). It is not limited to virtual reality technology and can operate on platforms that do not support VR or augmented reality (AR), where computer-generated images are overlaid onto the real world to enable real-time interaction with virtual content (Jans, Lucas, & Levett-Jones, 2023; Park & Kim, 2022b). Unlike traditional online platforms, the Metaverse continuously immerses users within the internet rather than simply providing access to it (Hollensen et al., 2022).

A defining feature of this immersion is the sense of presence—“the state or fact of existing, occurring, or being present” (Shen et al., 2021). Users create avatars, virtual representations of themselves, to interact with the environment and its content from multiple perspectives, fostering a psychological sensation of inhabiting a shared space (Park & Kim, 2022a). Presence is strengthened through communication and social interaction (Mystakidis et al., 2021), which build connections with others and can significantly influence both learning and social outcomes (Kreijns et al., 2022).

Several aspects distinguish the Metaverse from VR technologies. Studies describing VR primarily focus on physical characteristics and rendering (production of images that are indistinguishable from original sources) (Fernandez-Maloigne et al., 2023). Whilst the Metaverse is a collection of interconnected technologies, applications, and platforms that offer immersive experiences, content, and social interactions (Jans, Lucas, & Levett-Jones, 2023; Park & Kim, 2022b), virtual reality (VR), only grants access to the internet (Hollensen et al., 2022), and can essentially act as a portal into the Metaverse.

The gaming arena is one of the most significant driving forces behind the Metaverse (Wang et al., 2023). Multimedia platforms such as Second Life®, Roblox and Fortnite® were precursors to the Metaverse, providing users with opportunities to create avatars and interact with other gamers within their own virtual world (Damar, 2021; Dwivedi et al., 2022). Despite their availability and widespread adoption since the early 2000s, within the metaverse framework these platforms are constrained by their lack of platform independence (ability to operate consistently across different computing platforms or systems without requiring modification),

limited functionality (Dwivedi et al., 2022) and lack the immersion, interoperability and scalability provided in the more contemporary version of the Metaverse (Lee et al., 2021).

Although there is increasing interest in implementing the Metaverse within the business domain, there is limited evidence of its utilization, application and effectiveness in education. Early investigations of the Metaverse have primarily focused on its structural aspects and its role as a platform for exchanging interests and facilitating social interactions centered around content (Park & Kim, 2022a). While the Metaverse holds promise as a potential solution to the challenges and limitations of current online learning experiences, there remains a dearth of research examining its educational advantages and the impact on student experiences and performance.

A limited number of systematic, umbrella and scoping reviews have been conducted to investigate the use of the Metaverse in healthcare education. Previous reviews have focused on providing evidence of Metaverse use and ascertaining knowledge gaps related to nursing education (De Gagne et al., 2023), exploring the use of the Metaverse in healthcare, specifically illness prevention, treatment, patient education, training and research (Petrigna & Musumeci, 2022), use of Second Life® in nursing education (Irwin & Coutts, 2015), and the use of the Metaverse to improve humanistic skills (ability to relate to others on a human level, demonstrating empathy, understanding, and compassion) in healthcare (Gonzalez-Moreno et al., 2023). Results from these reviews indicate that the Metaverse can be adopted to improve healthcare education and training (Gonzalez-Moreno et al., 2023; Irwin & Coutts, 2015; Petrigna & Musumeci, 2022), assisting undergraduate nursing students to link theory to practice (Irwin & Coutts, 2015), and develop nontechnical skills, such as communication, empathy, confidentiality and respect (Gonzalez-Moreno et al., 2023). Nonetheless, these reviews also identified that the Metaverse is still in its infancy and there is a scarcity of empirical evidence to support its effectiveness in healthcare education, with further studies needed (De Gagne et al., 2023). More specifically, little research has been conducted in relation to the use of the Metaverse in simulation-based learning (SBL). SBL provides a broad spectrum of realistic and authentic clinical experiences, allowing learners to engage with a variety of simulation modalities, such as computerized patient manikins or standardized patients (actors) to prepare for real-world practice (Cant & Cooper, 2017; Cant et al., 2018). Currently, no systematic reviews have been identified that critically appraise the literature on the use, application and effectiveness of the Metaverse in simulation-based learning in nursing.

Objective

The objective of this mixed methods systematic review was to identify and critically appraise literature related to the utilization, application, and effectiveness of the Metaverse in simulation-based nursing education.

Methods and methodology

This study was conducted using the JBI Guidelines for Mixed Methods Systematic Reviews (MMSR) (Lizarondo et al., 2020). MMSRs combine findings from quantitative and qualitative evidence to enhance their usefulness to decision-makers. The synthesized results from several studies offer a more reliable and detailed evaluation of the effectiveness of interventions (Mertens, 2018). In accordance with the JBI methodology for mixed-methods systematic reviews, a convergent segregated approach was utilized (Stern et al., 2021), in which qualitative, quantitative, and mixed-methods analyses were conducted independently. All results were then synthe-

Table 1
Summary of Eligibility Criteria.

Inclusion	Exclusion
Undergraduate nurs*	Nonhealth related disciplines
Undergraduate nursing education	Other healthcare disciplines
Undergraduate nursing training	
Undergraduate healthcare education	
Undergraduate healthcare training	
Metaverse	Desktop
Virtual environment	Computer based
Virtual learning environments	Nonimmersive
Virtual world	
Virtual space	
Digital universe	
Cyberverse	
Cyberspace	
Mirror world	
Omniverse	
Education	K-12
University	Primary education
TAFE OR Technical and Further Education	Secondary education
College	Postgraduate
VET OR Vocational Education and Training	
Distance education	
Distance learning	
Remote learning	
Remote education	
Higher education	
Simulation	Language other than English
Simulated learning simulation education	Older than 2013.
Simulation-based experience	Abstract only
Simulation-based education	Commentaries
Simulation-based learning	Letters to editor
Simulation-based learning experiences	Conference proceedings
Patient simulation	Opinion articles
Clinical practice	Reviews
Clinical learning	
Experiential learning	
English language	
2013-2023	
Full text	
Case reports	
Peer reviewed studies	
Primary sources	

sized (Aromataris et al., 2024) to address the following research questions:

- What is known about the use of the Metaverse in simulation-based learning in nursing education?
- How is the Metaverse being utilized and applied to simulation-based learning in nursing education?
- How effective is the use of the Metaverse in simulation-based learning in nursing education?

A protocol was developed prior to conducting this systematic review; however, it was not registered in a formal registry. The methodology adhered to established guidelines, including PRISMA, to ensure a rigorous and transparent review process.

Eligibility criteria

Eligibility criteria are summarized in Table 1. Studies included were peer-reviewed, full text primary research studies, written in English and reporting on aspects of the Metaverse and its use, application and effectiveness in *simulation-based learning* for undergraduate nursing students, and published between 2013 and 2023. Studies that focused on registered nurses, other healthcare professionals, postgraduate students or nonimmersive VR were excluded from the review.

Table 2
Search Terms.

"undergraduate nurs*" OR "undergraduate nursing education" OR "undergraduate nursing training" OR "undergraduate healthcare education" OR undergraduate healthcare training AND metaverse OR "virtual environment" OR "virtual learning environments" OR "virtual world" OR "virtual space" OR "virtual reality" or VR or "augmented reality" or AR or "extended reality" or XR or "mixed reality" or MR OR "digital universe" OR cyberspace OR "mirror world" OR omniverse) AND simulation OR "simulated learning" OR "simulation education" OR "simulation-based experience" OR "simulation-based education" OR "simulation-based learning" OR "simulation-based learning experiences" OR "patient simulation" OR "clinical practice" OR "clinical learning" OR "experiential learning"

English language
2013 - 2023
Full text
Case reports
Peer reviewed studies
primary sources

Search strategy

A research librarian was consulted in the initial stages of designing the search strategy and a comprehensive search of eight electronic databases was conducted in August 2023. The literature search was conducted using Scopus, Web of Science, Education Research Complete (Smith et al., 2018), IEEE Xplore, ProQuest, Ebscohost, Cumulated Index to Nursing and Allied Health Literature (CINAHL) and PubMed using the search terms outlined in Table 2. The truncations and Boolean operators "OR" and "AND" were applied. Following this, hand searching of reference lists of included papers was undertaken. The search results from all databases were imported into Endnote 20™ reference management software (The Endnote Team, 2013) and then uploaded into Covidence™ for screening (Covidence, 2020).

The search was limited to sources published between 1 January 2013 and 31 July 2023. Despite a growing body of research in this area over the past several decades, since 2013 significant improvements in the quality and availability of VR hardware and the release of the first versions of head mounted displays (Saredakis et al., 2020) have made virtual technology more accessible (Jensen & Konradsen, 2018, p. 1516). Therefore, only the last ten-year period was included in this review.

Selection process

The study identification and selection process are presented in a PRISMA flowchart (see Figure 1). All identified citations were transferred into Covidence™ (Covidence, 2020) for screening and review. A total of 1085 papers corresponding to the search terms were initially identified. After removal of duplicates, the number of relevant articles was reduced to 828. Title and abstract screening were conducted independently in detail against the inclusion/exclusion criteria by two reviewers (CJ & CL), with any discrepancies addressed by the third reviewer (TLJ). A further 701 studies were removed that did not meet the criteria. The remaining 127 studies underwent full-text review, during which 95 studies were found to not meet all inclusion criteria. This resulted in a total of 32 studies being included in the review. Reference lists of the remaining 32 studies were reviewed for potential inclusion but did not yield any additional studies.

Methodology

Data were extracted and tabulated across seven criteria: country; aim; method/design; sample; outcome measures; key results; and limitations (see Table 2). A convergent integrated approach was undertaken with the synthesis of the qualitative, quantitative

and mixed methods data occurring simultaneously, as guided by the JBI Manual for Evidence Synthesis (Aromataris et al., 2024).

Critical appraisal

Included studies were critically appraised using the Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018). This is a valid instrument for assessing the quality of studies in mixed methods systematic reviews (Souto et al., 2015). Appraisal was conducted using the appropriate set of questions tailored to the required study design, using a response scale of Yes/No/Can't tell. The quality appraisal scores are provided in Table 1. Overall, the quality of the studies was generally high with 16 of the 32 studies scoring 5* (or 100% quality criteria met), 3 studies scoring 4** or 80% quality criteria met, and 5 studies scoring 3*** or 60% quality criteria met). Eight studies were deemed to be of low quality scoring a 2** (Chan & Leung, 2018) or 1* (Barteit et al., 2021). As these studies met the inclusion criteria and provided relevant data related to the topic, they were still included in the review (refer to Table 2).

Results

Study characteristics

The 32 studies described in the papers included in the review were conducted in multiple countries, including ten each in Korea and the USA, three in Taiwan and one study each in Belgium, China, Finland, Germany, Hong Kong, Ireland, Scotland, Singapore, and South Africa. All studies were conducted between 2016 and 2023. Of the 32 studies, 14 adopted a quantitative approach, 12 utilized mixed methods approaches and 6 used a qualitative approach.

Twenty-six studies utilized quantitative data collection methods (14 quantitative and 12 mixed methods), including one randomized control trial (RCT), one non-RCT, three cross-sectional studies, seven quasi-experimental studies, two control group studies, two pre-post-test studies, one study utilizing an A-B-A design and one adopting a cross-over design. A further eight studies adopted only a post-test design. Twenty-three of the 26 studies utilized at least one validated tool, with the System Usability Scale being the most common ($n = 4$). Cronbach alphas for these scales ranged from 0.79 to 0.96. Three studies utilized tools specifically developed for the study and validated by content experts. Sample sizes in the 26 studies ranged from 12 to 300 participants, with only six of the studies calculating the required sample size.

In the qualitative studies, eight used focus groups, three adopted open-ended interviews, two utilized semi-structured interviews, and six employed open-ended questionnaires. For data analysis, eight studies used thematic analysis and two employed content analysis. Of these later two studies, inductive content analysis, deductive analysis or a combination of both types were adopted. Three studies did not specify how the data was analyzed.

Learning outcomes and learner experiences

This review identified limited evidence specifically related to the utilization, application and effectiveness of the Metaverse in SBL in nursing education. However, components of the Metaverse, such as the technologies (eg, VR, AR) and affordances (e.g. presence and immersion) were identified within the included studies, related to two broad themes: (a) learning outcomes and (b) learner experiences. Learning outcome measures were related to knowledge, skills, self-efficacy, confidence and motivation. Learner experiences focused on satisfaction, presence and immersion, usability, acceptability and anxiety and stress (see Diagram 1). An overview

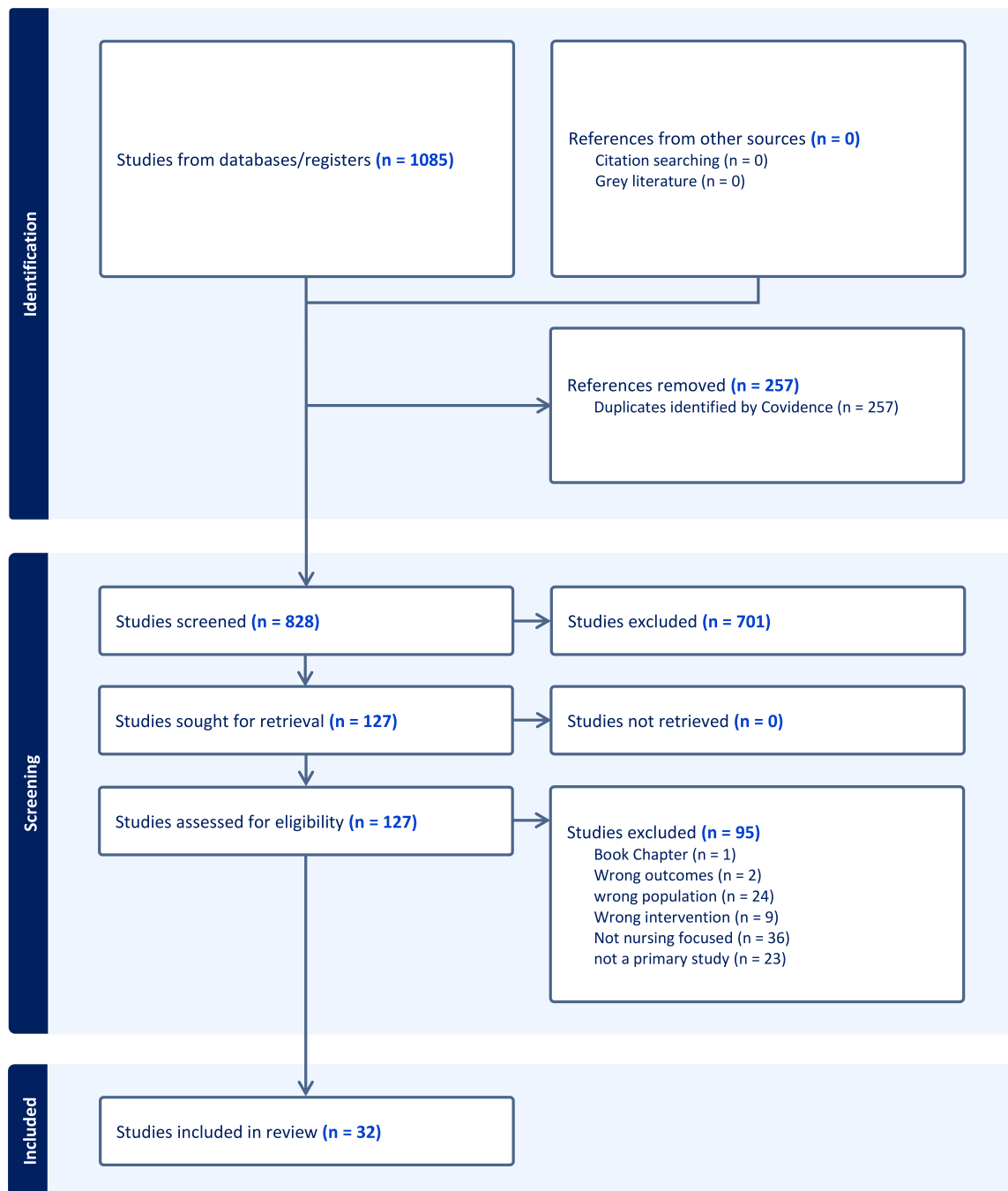


Figure 1. Flow Diagram of the PRISMA statement (Covidence, 2020).

of the results of the Metaverse modalities and outcomes are outlined in Table 3.

Learning outcomes

Knowledge acquisition. Knowledge, related to the use of metaverse technologies, was the most frequently assessed learning outcome with a total of eleven studies. All eleven studies adopted the use of virtual reality to enhance knowledge. Various quantitative data collection methods were employed; six studies used a pre-post-test design, three adopted multiple group comparisons, one used single pre-post-test and one used a group post-test design. Results varied across studies. Multiple studies demonstrated significant improvements in knowledge levels for experimental groups compared to control groups in areas such as knowledge of infection control

practices (Yu & Yang, 2022), pre and postoperative care for chemoport insertion (Jung & Park, 2022), and neonatal resuscitation (Yang & Oh, 2022). In some studies there was no significant difference between groups, such as studies examining knowledge of mechanical ventilation (Lee & Han, 2022), high-risk neonatal infection control (Yu et al., 2021), and mental health nursing (Lee et al., 2022). Conversely, one comparative study found no significant differences between VR, video, and written case studies in knowledge acquisition, suggesting that VR can be as effective as other modalities for theoretical learning (Hoyt & Hauze, 2023).

Clinical skill development. Both technical and nontechnical skills were examined in the included studies. Nontechnical skills included problem-solving, clinical reasoning and critical thinking,

Table 3
Methodological Characteristics and Summary of Main Findings of Included Studies.

Author/s, Year, Country	Aim	Method/Design	Sample	Outcome Measures	Key Findings
Yu et al., 2021 Korea MMAT: 5	To examine the effects of a virtual reality simulation program on nursing students' knowledge, performance self-efficacy, and learner satisfaction.	Nonequivalent control group design. Data collection and analysis using descriptive statistics and statistical tests	Senior nursing students (n = 50)	Knowledge assessed using the High-Risk Neonatal Infection Control Competency Scale Knowledge (HirNICCS_K) developed by Yu et al. (2021). The reliability for the overall scale was KR-20 0.61 in this study. Self-efficacy was assessed using a modified version of a self-efficacy measure employed in a previous nursing student simulation study and modified based on the High-Risk Neonatal Infection Control Competency Scale Performance by Yu et al. (2021). Cronbach's α of 0.96 Learner satisfaction was measured using three items developed by Cho (2018), using a 5-point Likert scale. Cronbach's α of 0.81	Experimental group showed greater improvements in high-risk neonatal infection control performance self-efficacy. Experimental group showed greater learner satisfaction compared to control group. VR simulation program improved nursing students' performance self-efficacy. VR simulation program increased learner satisfaction. VR simulation programs have potential benefits compared to traditional simulations.
Yu & Yang., 2022, Korea MMAT: 5	Assess the effects of a virtual reality infection control simulation program on PPE knowledge, infection control performance, and self-efficacy. Evaluate the realism and satisfaction of the program among participants.	Quasi-experimental study with controlled pretest-post-test design Data collected through online pre-intervention and post-intervention surveys	3rd and 4th-year nursing students (n = 50)	PPE knowledge measured using tool originally developed by Choi for PPE knowledge related to acute respiratory infection, modified and supplemented to be suitable for study. Content validity index of the tool at the time of development was 0.8-1.0 for each item, while the Kuder-Richardson Formula 20 (KR-20) of the knowledge items in the study was 0.68. Infection control performance measured based on items related to PPE and pediatric respiratory care. PPE-related items measured using tool originally developed by Kwon, modified and supplemented according to the actual performance procedures of this study. Consists of 20 items, rated on a 5-point Likert score. Cronbach α of 0.97 in this study Self-efficacy measured using the tool developed by Ayres and adapted by Park and Kwon for simulation studies. Consists of 10 items, rated on a 7-point scale. Cronbach α of 0.94 in this study Realism of the VRICS program measured using the items corresponding to realistic immersion within the tool for measuring presence developed by Chung and Yang, using a 5-point Likert scale. Cronbach α was 0.76 in this study Level of satisfaction with the program measured using 3 items developed by Yu et al. (2021). and modified for this study. Each item was rated on a 5-point Likert scale. Cronbach α was 0.81 in this study.	Experimental group showed significant improvements in PPE knowledge, infection control performance, and self-efficacy. Mean scores for realistic immersion and learner satisfaction were high. VR simulation training effectively enhanced theoretical knowledge and respiratory care skills. Combining VR simulation and skills training was more effective than conventional instruction. Program enhanced theoretical knowledge, respiratory care skills, and infectious disease preparedness. Program could be applied to training nurses for public health situations involving infectious diseases.

(continued on next page)

Table 3 (continued)

Author/s, Year, Country	Aim	Method/Design	Sample	Outcome Measures	Key Findings
Yang & Oh, 2022, Korea MMAT: 5	To examine the effects of a neonatal resuscitation gamification program using immersive virtual reality.	Quasi-experimental, nonrandomised control simulation study with a pre-test post-test design.	Prelicensure nursing students. (n = 83)	<p>Neonatal resuscitation knowledge measured using the Neonatal Resuscitation Nursing Knowledge Measurement Tool standardized by Yoo (2013). Comprises 30 questions on the following: appearance, pulse, grimace, activity, respiration (APGAR) score measurement, initial assessment and intervention, aspiration, oxygen saturation measurement, nasogastric tube insertion, oxygen supply, chest compression, endotracheal intubation, medication, and anatomical knowledge. The Kuder Richardson estimator formula 20 (KR-20) 0.78 in this study.</p> <p>Problem-solving ability measured using the problem-solving ability of adults by Lee et al. (2008). Comprises 30 questions across five sub-fields using a five-point Likert scale. Cronbach's α was 0.94 in this study.</p> <p>Clinical reasoning ability measured using the Korean version of Nurses Clinical Reasoning Scale developed by Jung & Han (2017). Consists of 15 questions measured on a five-point Likert scale. Cronbach's α was 0.96 in this study</p> <p>Self-confidence in practical performance measured using tool by Yoo (2013). Consists of 15 questions: item inspection, initial intervention, APGAR score measurement, situational judgment, aspiration, pulse oximeter application, oxygen supply, nasogastric tube insertion, chest compression, medication, reporting, condition observation, documentation and endotracheal intubation using a five-point Likert scale. Cronbach's α was 0.95 in this study</p> <p>Degree of anxiety measured using a tool translated into Korean by Kim and Shin (1978) from the State Trait Anxiety Inventory (STAI) developed by Spielberger (1970). Consists of 20 questions related to state anxiety, measured on a four-point Likert scale. Cronbach's α was 0.90 in this study.</p> <p>Learning motivation measured using the Learning Motivation Test Paper by Song & Keller (2001). Consists of five sub-fields with 30 questions using a five-point Likert scale. Cronbach's α was 0.88 in this study</p>	<p>Neonatal resuscitation knowledge and learning motivation were significantly higher in the virtual reality and simulation groups compared to the control group.</p> <p>Problem-solving ability and self-confidence were significantly higher in the virtual reality group compared to the simulation and control groups.</p> <p>Anxiety was significantly lower in the simulation group compared to the virtual reality and control groups.</p> <p>The neonatal resuscitation gamification program using immersive virtual reality was effective in increasing knowledge, problem-solving ability, self-confidence, and learning motivation of nursing students.</p> <p>Immersive VR showed positive effects.</p> <p>Could replace on-site training in areas with limited resources.</p>

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Table 3 (continued)

Author/s, Year, Country	Aim	Method/Design	Sample	Outcome Measures	Key Findings
Wu et al., 2021, China MMAT: 5	To explore students use of VR for enhancing their general subject learning and specific English vocabulary learning To address the following questions: What are the affordances of VR learning in an ESP nursing course? What are the constraints of VR learning in an ESP nursing course?	Exploratory study	2nd year nursing students (<i>n</i> = 10)	6-point Likert-scale questionnaire adapted from McGill and Hobbs (2008) to understand students' perceptions and attitudes Semi-structured interviews to understand students' VR learning experience Thematic analysis of interview transcripts to identify emerging themes	Learners appreciated the different features of VR in language learning. Suggestions for designing VR-supported language learning were proposed. VR has benefits in training nursing students in immersive English learning. Affordances and challenges coexist in VR-supported language teaching. Future research should investigate the effectiveness of learning in immersive contexts. Large-scale VR studies are needed for a comprehensive understanding in different contexts. Teacher training in VR-assisted language education is a key issue. Students appreciated the learning opportunities afforded by VR technology.
Vaughn et al., 2016, USA MMAT: 2	To enhance realism in clinical simulation. To increase the perception of realism for prelicensure nursing students. To give students confidence in developing skills and knowledge for clinical tasks.	Pilot study	Prelicensure nursing students (<i>n</i> = 12)	Simulation design scale (SDS) - 20-item instrument that evaluates the design features of instructor developed simulations related to the feasibility of the simulation, using a 5-point scale. Cronbach α = 0.92–0.96 Self-confidence in learning scale (SCLS) - 13-item instrument designed to measure student satisfaction with a simulation activity and self-confidence in learning using a 5-point scale. Cronbach α = 0.83–0.92	Students reported that the simulation enhanced their perception of realism. Students felt more connected to the patient and had a better understanding of the clinical situation. Students found the use of ARH technology to be helpful and effective. The integration of ARH improved the simulation-learning environment. The simulation increased students' confidence in their skills and knowledge. High-fidelity simulation is an effective teaching strategy for recognizing patient conditions. Augmented reality technology can enhance and improve simulation-based learning. Further research is needed to determine the impact of augmented reality.
Traister, 2023, USA MMAT: 5	To investigate the influence of full immersion virtual reality simulation on nursing students' anxiety levels. To assess the communication skills of nursing students when interacting with anxious patients. To utilize an algorithm-based analytics system to evaluate communication skills. To explore the potential of full immersion virtual reality simulation as a learning tool in nursing education.	Quasi-experimental design	Nursing students (<i>n</i> = 33)	Participants' anxiety levels assessed using Spielberger's short-form State Anxiety Inventory Communication skills evaluated using the simulation's analytics dashboard	Statistically significant decrease in students' anxiety levels over time. No significant improvement in participants' communication scores. Full immersion VRS reduces nursing students' anxiety with anxious patients. Further exploration of VRS in nursing education is needed.

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Table 3 (continued)

Author/s, Year, Country	Aim	Method/Design	Sample	Outcome Measures	Key Findings
Smith et al., 2018, USA MMAT: 2	Evaluate the impact of two different decontamination VRS interfaces on nursing student learning and performance	Quasi-experimental design with repeated measures Focus groups	(n = 197)	Performance measured using researcher developed decontamination checklist. Knowledge measured using cognitive exam based on Federal Emergency Management Association (FEMA IS-346) Focus groups to measure students' satisfaction and experience of IVR.	Cognitive scores were higher immediately after treatment and lower at retention measurement. Performance scores were higher immediately post-training than at six months post-training. No significant differences were found between intervention groups based on cognitive test scores or time to completion. The only significant difference in performance was between the computer-mouse group and the written instruction group immediately post-training. Gaming experience and gender had an impact on performance scores. Qualitative analysis indicated high levels of satisfaction with both VRS interfaces. VR is a useful tool for teaching students. Learning occurred with different levels of immersive capability in VRS. VRS offers a cost-effective solution for disaster preparation. More studies needed to develop best practice guidelines for VRS in nursing education.
Saab et al. (2022), Ireland MMAT: 5	To explore nursing students' views on using virtual reality in healthcare.	A qualitative descriptive design	3rd year nursing students (n = 26)	Focus groups were conducted to collect participants' views on using virtual reality in healthcare.	Four themes were identified: (a) positive experiences of virtual reality; (b) challenges to using virtual reality; (c) settings where virtual reality can be implemented; and (d) blue-sky and future applications of virtual reality. Participants found VR to be interactive, immersive, and engaging. Participants perceived VR as more memorable than traditional health education strategies Participants also believed that VR caters for different literacy levels and learning styles and provides the user with ample privacy. Participants believed that VR was more suitable for use in outpatient rather than inpatient settings. A few participants complained of dizziness and motion sickness which subsided within a few minutes to one hour following the intervention Participants recommended more training and guidance for using VR. Participants perceived technology was more suitable for younger and middle-aged users rather than older adults

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Table 3 (continued)

Author/s, Year, Country	Aim	Method/Design	Sample	Outcome Measures	Key Findings
Plotzky et al. (2023) Germany MMAT: 2	Investigate effects on educational outcomes through different learning modalities for nursing students learning the ETS procedure.	Pre-post-test design for knowledge assessment objective structured clinical examination for skill assessment Standardized questionnaires for learning satisfaction and technology acceptance Focus groups	Nursing students (n = 131)	Knowledge acquisition assessed through pre-post-test design - self-developed knowledge test consisting of eight multiple-choice items + two further items where the individual steps of conducting ETS had to be placed into the correct order. Learner satisfaction assessed through affective-behavioral-cognitive-satisfaction questionnaire (ABC-SAT) - 11 items, divided into the three subscales: affective, behavioral, and cognitive satisfaction using a 5-point Likert scale. Only the six items from the cognitive satisfaction subscale were considered relevant in the context of the study and were included. Technology acceptance assessed through an adapted version of the virtual reality hardware acceptance model (VR-HAM) - a 23-item tool with five subscales (perceived usefulness, perceived ease of use, perceived enjoyment, intention to use, and attitude towards using VR hardware) using a 5-point Likert scale.	All three groups significantly improved their theoretical knowledge. No significant differences between the groups in knowledge acquisition. VR and videos can effectively be used to acquire knowledge in nursing education. Participants wanted the patient to show more reactions during the simulation. VR can be used to acquire knowledge in nursing education similar to video training. Video training is more successful than VR in conveying practical skills. VR users may be preoccupied with unfamiliar technology, affecting skill performance. Blended approach of video training and VR simulation is recommended. VR has the potential to increase learner satisfaction, motivation, and confidence. More research is needed to compare the effectiveness of video and VR training in nursing. VR simulations should be designed effectively with improved haptics for better outcomes.
Park and Kim (2022b), Korea MMAT: 5	Examine the mediating effect of learning immersion on instructional design and educational satisfaction in virtual environment simulation. Evaluate learner satisfaction with virtual environment simulation in nursing education. Provide useful information for nursing faculty in designing educational programs using virtual environment simulation. Establish consistent standards for instructional design in virtual environment simulation.	Descriptive cross-sectional research design Online questionnaire	Korea	Instructional design measured using the Korean version (Yoo & Kim, 2018) of the Simulation Design Scale, developed by National League for Nursing (2005). Consists of 21 items using 5-point Likert scale. Cronbach's α was 0.92 in this study. Learning immersion measured using the Learning Immersion in Simulation Scale - 16-item questionnaire using a 5-point Likert scale. Cronbach's α was 0.90. Educational satisfaction was measured using the Educational Satisfaction Scale in Simulation for Nursing Students by Kim and Heo (2019). Comprises of 16 items using a 5-point Likert scale. Cronbach's α was 0.78 in this study.	Instructional design in virtual environment simulation affects educational satisfaction. Learning immersion has a partial mediating effect on the relationship between instructional design and educational satisfaction. VE simulation-based educational content should be implemented with high-quality instructional design. Instructors should consider factors that promote educational satisfaction in VE simulation. The study provides useful information for nursing faculty designing teaching methods in a new environment. The study can be used as a reference for further research on VE simulation.

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Author/s, Year, Country	Aim	Method/Design	Sample	Outcome Measures	Key Findings
Paquay et al., 2022, Belgium	To investigate to what extent users social and internal factors might influence the Sense of Presence (SoP) and to further identify members of occupations characteristics influencing immersive experiences	A cross-sectional study	83 undergraduate students: 35 nursing students 24 medical students 24 ambulance attendees	Sense of Presence (SoP) measured using the Questionnaire sur l'Etat de Presence (PQ-F). The Questionnaire sur Etat de Presence (PQ-F) was used for this study, a French-language validated adaptation of the Presence Questionnaire to measure the SoP - 38 item instrument using a 5-point Likert scale. Validated French adaptation of the Immersive Tendencies Questionnaire (ITQF) French-language adaptation of the Ways of Coping Checklist (WCC) from Lazarus and Folkman - 27 items using a 4-point Likert scale. Inventaire rationnel-experientiel - validated French-language adaptation of the Rational-Experiential Inventory (REI). 40 item questionnaire using a 5-point Likert scale. French-language adaptation of the Simulator Sickness Questionnaire was used to monitor possible side effects. 16 item questionnaire using a 4-point Likert scale. Stress level assessed by a self-reported scale and The Mental Readiness Form (MRF). The first is a Visual Analog Scale (VAS) for measuring participants' stress levels, from 0 to 10 pre and post simulation. The MRF is composed of 3 11-point scales addressing cognitive, affective, and physiological levels perception of stress.	Sense of Presence (SoP) was associated with gender, disaster medicine education, propensity for immersion, and members of occupations. Immersion characteristics specific to occupational categories were identified. Personal differences were discovered between ambulance attendants, student nurses, and medical students. Significant differences in Sense of Presence (SoP) among different healthcare occupations. Consideration of occupational differences when designing VR training. Need for a more comprehensive definition of SoP in the literature. Further investigation of cognitive processes related to prior experience and memory. Identification of the level of experience needed for a sufficient SoP.
Makinen et al. (2020) Finland MMAT: 5	The aim of the study was to describe nursing students' user experiences of immersive virtual reality simulation.	Qualitative descriptive study	Graduating nursing students (n = 41)	System Usability Scale (SUS) was used to assess usability. SUS scores ranged from 0 to 100, with 100 being the best possible score. Semi-structured individual interviews were conducted using a model of UXs in immersive virtual environments.	User experiences emphasised three themes about the highly immersive VR simulation. Usability was evaluated as fair (SUS score 62.3 out of 100). The VR simulation was easy to use with the support of a technical person. The study supports the use of highly immersive VR simulation for nursing education. Technical assistance is crucial when adopting new technologies in education. The importance of UX in an education context was highlighted. Highly immersive VR simulation is beneficial for nursing education.
Lee et al., 2022, Korea MMAT: 5	To optimise learning experience in mental-health nursing education using virtual reality simulation with 360-degree video.	Pre-and post-test control group design	Nursing students (n = 104)	Knowledge assessed using 18 question MCQ validated by two faculty members. Problem-solving measured using 30-item questionnaire (Lee et al., 2008). Consisted of five factors, including clarifying problems, seeking a solution, decision-making, applying solutions, and evaluating and reflecting. 5-point Likert scale Learning satisfaction measured using 9-item questionnaire developed by Kim and Ha (2020) and modified for study. 5-point Likert scale. Items included: usefulness of learning experience, content satisfaction and perceived program effectiveness.	VR simulation improved knowledge and problem-solving abilities in nursing students. 360-degree video VR simulation showed statistically significant improvement in decision-making, solution-applying, and evaluation-reflection. 2D video clips did not show statistically significant improvement in problem-solving ability. VR simulation group had a higher level of learning satisfaction compared to the control group. VR simulation bridges the gap between theoretical education and clinical practice. Further studies, such as randomized controlled trials, are needed for validation.

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Table 3 (continued)

Author/s, Year, Country	Aim	Method/Design	Sample	Outcome Measures	Key Findings
Lee et al. (2020) Korea MMAT: 3	Evaluate the usefulness of VR simulation for mental health nursing education. Explore users' experiences in terms of ease of use and perceived usefulness.	Mixed methods study with quantitative and qualitative questionnaires	Nursing students. (n = 60)	Usability test conducted using a 17-item quantitative rating scale questionnaire. Scale ranging from 0 to 10 for responses Cronbach's alpha for questionnaire was 0.911	Wide variation in academic achievement and perceived competency in communication. One out of five students reported poor academic achievement. 16 participants reported a lack of competency in communication. Most participants did not have previous experience with VR. VR simulations are useful and effective alternatives for nursing education. Nursing students can use VR technologies for educational purposes. VR-simulated scenarios with schizophrenia patients have potential to improve treatment competency. VR simulation program improved self-efficacy, clinical reasoning capacity, and learning satisfaction. Learning satisfaction was higher in the experimental group compared to the control group. VR was effective in improving nursing competence. - VR for mechanical ventilation improves nursing competence. VR enhances self-efficacy, clinical reasoning capacity, and learning satisfaction.
Lee & Han, 2022, Korea MMAT: 5	To develop and evaluate a virtual reality mechanical ventilation education program for nursing students.	Quasi-experimental design.	4th-year students (n = 66)	Knowledge measured using 10 item questionnaire developed by researchers and validated by three nursing professors. Reliability of scale was 0.70 based on Kuder-Richardson formula 20 Self-efficacy measured using 10-item questionnaire developed by Ha and Koh. Cronbach α for this study was 0.78 Clinical reasoning capacity was measured using a 15-item scale scored on a 5-point Likert scale developed by Liou et al., translated into Korean. Cronbach α 's were 0.94, 0.93, and 0.90 Learning satisfaction was measured using the Numeral Rating Scale (NRS), scored as 10 points for very satisfied and 0 points for very unsatisfied. Learning immersion measured using the Flow Short Scale developed by Engeser and Rheinberg, translated into Korean. 10 items measured on a 5-point Likert scale. Cronbach α 's were 0.92, 0.84, and 0.94.	
Lau et al. (2023), Singapore MMAT: 3	Examine the impact of IVR clinical procedures on mid-career switch students in knowledge, game perception and user reaction. Explore the mid-career switch students' perceptions and experiences in using the IVR clinical procedures.	A mixed methods feasibility study	1st-year mid-career switch (n = 51)	Single-group pretest and post-test questionnaire consisting of 20 items relating to intravenous therapy and subcutaneous insulin procedures. User Reaction Survey. Cronbach's α for this study was 0.84 Game Perception Scale. Cronbach's α for this study was 0.88. Focus groups using semi-structured interviews. Analyzed using thematic analysis.	Significant improvement in knowledge for subcutaneous insulin. No statistically significant increase in combined scores for intravenous therapy and subcutaneous insulin. Three overarching themes emerged: learning and practice, challenges and barriers, personal attributes. Participants found the experiences engaging, relevant, and satisfying. Some participants experienced giddiness, headache, and lack of familiarity with technologies. IVR simulation can be used as a supplementary learning tool for mid-career switch students. IVR clinical procedures can enhance knowledge acquisition and experiential learning. IVR is a promising approach to improve confidence in performing clinical procedures. More research is needed to explore the effectiveness of IVR on skill acquisition and competence.

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Author/s, Year, Country	Aim	Method/Design	Sample	Outcome Measures	Key Findings
Kim & Ahn, 2021, Korea MMAT: 5	To identify the effects of cognitive and emotional variables related to immersive virtual reality media technology on learning for nursing students	Descriptive research study	Nursing students (n = 121)	Learning effects of virtual reality medium measured using multimedia learning effect developed by Kim and modified to be applied to the virtual reality system. Consists of 5 items using a 5-point Likert scale. Cronbach's alpha was 0.81. Virtual reality technology recognition - tool consisting of 5 items using a 5-point Likert scale. Cronbach α was 0.76. Personality Traits measured using The Big Five Index, a 22-item tool using a 6-point Likert scale. Cronbach's α was 0.82 for Neuroticism, 0.80 for Openness, 0.71 for Conscientiousness, 0.80 for Extraversion, and 0.71 for Affinity. Satisfaction of virtual reality learning measured using tool developed by Stein and modified by Gye. Consists of 4 items using a 5-point Likert scale, Cronbach's α was 0.84.	Learning effects of virtual reality medium had positive correlation with various factors. Personality traits of openness, extraversion, and conscientiousness had positive correlation. Learning satisfaction, sensory immersion, continuous use intention, and extraversion were significant influencing factors. Explanatory power of learning effect of virtual reality medium was 63.9%. Factors influencing learning with virtual reality technology were identified. Insights for developing virtual reality-based learning programs were provided. Consideration of cognitive and emotional variables is important in virtual reality learning. Virtual reality can be used as an auxiliary medium for related learning. Further research is needed on different types of learning and interventions for physical discomfort.
Jung & Park, 2022, Korea MMAT: 5	To develop a mobile head mounted display (HMD)-based virtual reality (VR) nursing education program (VRP), and to evaluate the effects on knowledge, learning attitude, satisfaction with self-practice, and learning motivation in nursing students	Quasi-experimental study using a nonequivalent control group pretest-post-test design	2nd, 3rd & 4th-year students (n = 60)	Knowledge measured using 10-item questionnaire. Developed by researchers and verified by two nursing professors and one expert with a doctorate degree in nursing and more than 10 years of clinical experience. Content validity index (CVI) was 0.9. Learning attitude assessed using 16-item tool on self-concept, study attitude, and learning habits. The items were evaluated on a five-point Likert scale. The reliability of the tool was 0.71 in this study. Satisfaction measured using modified tool. The tool originally consisted of 24 items at the time of development. In this study, the number of items was reduced to 17. Two nursing professors evaluated the content validity of the items. The CVI was 0.95. Consisted of the following domains: learner attitude, learner satisfaction, appropriateness of learning content, learning achievement, motivation, debriefing, and self-reflection. Each item was evaluated on a five-point Likert scale.	HMD-based VRP improved postintervention knowledge, learning attitude, and satisfaction. Motivation, attention, and relevance were significantly different between the two groups. HMD-based VRP is expected to contribute to knowledge, learning attitude, satisfaction, attention, and relevance in nursing students. HMD-based VRP improved knowledge, learning attitude, and satisfaction in nursing students. Motivation, attention, and relevance were significantly different between the two groups. Further research is needed to verify the effectiveness of VRP.

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Author/s, Year, Country	Aim	Method/Design	Sample	Outcome Measures	Key Findings
Hoyt & Hauze, 2023, USA MMAT: 4	Assess acceptability and usability of a VR simulator for procedural training.	Stratified random research design	Baccalaureate nursing students (n = 161)	Pre-post survey VSP case study	Differences existed between research groups in terms of student knowledge, skill, and motivation to learn surrounding an evolving anaphylaxis scenario. 2D video and 3D simulation outperformed the written case study in terms of attention, relevance, confidence, and satisfaction. 3D HoloLens modality outperformed both the 2D video and the written case study in terms of attention and satisfaction. Overall motivation to learn was compared between the three teaching methods. VR simulator for procedural training skills is acceptable and usable. No significant difference in acceptability based on age, gender, or expertise. VR simulator can be used extensively in initial or vocational training. Future development includes designing scenarios for teaching nontechnical skills.
Hannans et al., 2021, USA MMAT: 5	Explore aspects of learning in terms of gain in knowledge, confidence and empathy with immersive virtual reality (VR) from the patient perspective in undergraduate nursing students.	Mixed-methods design A pilot study Quantitative and qualitative data were collected through pre- and postsurveys	Nursing students (n = 165)	Quantitative and qualitative data were collected through pre- and postsurveys developed by Embodied Labs for each scenario, modified and adapted to produce a survey specific for this study. The surveys were validated by content experts.	Patient empathy and understanding - although students expressed relatively high levels of empathy and understanding prior to their VR experience, their levels of empathy grew across most measures after the VR intervention. Results suggest that the Embodied Labs experience was associated with students gaining a greater understanding of the perspective of an older patient. Confidence in providing care - students reported substantial growth in their confidence in providing care of patients in the early, middle and late stages of Alzheimer's disease. Students reported being the most confident in providing care to those in the early stages of the disease (postsurvey mean = 3.901) but experienced the most growth (32%) in their confidence in providing care for those in the late stages of the disease (presurvey mean = 2.722 to postsurvey mean = 3.606). Nursing skills and knowledge - Embodied Labs scenarios also were found to support students' nursing skills and knowledge.
Farra et al., 2018, USA MMAT: 5	to provide new evidence in how varying levels of immersion are perceived by nursing students using disaster-based VRS educational experiences.	Qualitative design.	Senior baccalaureate nursing students (n = 100)	Focus groups with 6 to 10 participants until the data saturation point was reached, which was 32 total students Moderators used reflective listening using four strategies described by Fern (2001) to ensure nonjudgmental discussion and the inclusion of all voices: clarifying, paraphrasing, reflecting feelings, and summarizing.	Four major categories, each with subcategories, were identified and linked to key components of the NLN Jeffries simulation theory: 1. simulation learning experience/facilitator educational strategies, 2. simulation design, 3. participant outcomes, 4. participant simulation experience.

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Author/s, Year, Country	Aim	Method/Design	Sample	Outcome Measures	Key Findings
Dang et al., 2018, USA MMAT: 3	To compare three learning modalities: active participation, VR observation, and television (TV) observation	A-B-A design	Nursing students (n = 47)	Immersive Tendencies Questionnaire (ITQ) - predicts a subject's inclination toward being immersed in mediated environments (Cronbach α 0.81). Presence Questionnaire (PQ), 29-item tool. Comprises four subscales: (a) sensory fidelity. (b)involvement, (c) adaptation/immersion & (d) interface. Cronbach α 0.91.	Subjects in the VR track had a significantly lower mean ITQ-involvement score (mean [M] =25.20; interquartile range [IQR] =21.75-30) than students in the All-Sim (M = 32.78; IQR =31-37; p =.04) and TV tracks (M = 32.41; IQR =29-38; p =.01). There were no significant differences between tracks on ITQ-Focus score (p > .05) or ITQ-Games score (p > .05). All-Sim experienced significantly greater presence Performance Outcomes: Scores for the IVR training group were significantly higher for the subdomains of infection control, initial assessment, and oxygen therapy compared to the hospital-based training group. No significant differences between the groups in focused assessment, medication administration, and evaluation Total performance scores were significantly higher for the IVR group compared to the hospital-based training group. The overall mean effect size of the IVR training versus the standard hospital training at post-test was moderate-to-large (d = 0.69). Acceptability of IVR Training: Provided a learning environment where they were exposed to different medical conditions they may not experience in clinical Described IVR as realistic + able to take on role of RN and make decisions
Cieslowski et al., 2023, USA MMAT:2	To develop and test an IVR acute care pediatric practice training program as an alternative to standard hospital training. The specific aims were to (a) assess the preliminary performance outcomes of IVR in comparison to standard training and (b) assess the acceptability of the IVR training as an alternative to standard training among undergraduate junior-level prelicensure nursing students.	Mixed-methods Quasi-Experimental Pilot Study	Junior-level prelicensure nursing students (n = 48)	Performance outcome data - Blinded research assistants collected the performance data for each student individually using an observer checklist adapted from Elsevier's Simulation Learning System for RNs 1st Edition. 19-item observation checklist assessed specific subdomains relevant to caring for a pediatric patient experiencing an acute asthma exacerbation 60-minute focus group was held to evaluate the acceptability of the IVR intervention as an alternative to hospital-based clinical experience	The order of using the simulators (desktop and immersive) had no significant effect on the results of KT, UAQ and SUQ The immersive version of the simulation system was relatively better accepted by the participants although the result was not statistically significant Using desktop computer or immersive device is not a critical concern in the implementation of VR simulation, from the aspects of acceptance and usability. More interesting, fun and engaging to use the immersive simulator. Realistic features and interactions in IMS
Choi, 2022, Hong Kong MMAT: 4	Investigate the acceptance and usability of the VR wound dressing simulation system	Crossover design	Nursing students (n = 30)	Knowledge test (KT) consisting of 20 MCQ User acceptance questionnaire (UAQ), a self-reported questionnaire with 13 items on four aspects technology acceptance, namely, perceived usefulness, perceived ease of use, intention to use, and attitude towards using the system using a 7-point Likert scale. System usability questionnaire (SUQ) containing eight items on a 7- point Likert scale, evaluating usability from the aspects of simplicity of use, simplicity of learning to use, comfort of use, effectiveness, efficiency, and productivity.	

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Author/s, Year, Country	Aim	Method/Design	Sample	Outcome Measures	Key Findings
Chen & Liou, 2022, Taiwan MMAT: 2	To understand the learning experiences and feelings of nursing students studying obstetrical nursing towards VR interactive experiences.	Qualitative design using interviews and feedback forms	Nursing students (n = 42)	Interviews Feedback forms	4 themes emerged: Inspiring empathy - VR has the effect of stimulating the senses, and enhances the feeling of being in a situation Improving nurse-patient communication skills - In VR, students can switch the nurse's and the mother's first-person point of view, providing a variety of scenarios in which the nurse and the patient communicate with each other, enhancing communication skills and in turn improving nurse-patient relationship. Stress-free learning environment - VR creates a self-directed and stress-free learning environment. Increasing interest in learning and self-confidence - In VR, students can do things repeatedly to enhance their proficiency and skills, so their interest in learning and self-confidence is increased in a virtual environment Theme 1: convenient to practice but requires adaptation - the VR environment was responsive to hand touch, making gestures easier to learn. The only requirement for the practice was a small space, thus not requiring classrooms, fake patients, and other consumable equipment. Although the learning process was made easier, students had to spend time learning and adapting to VR Theme 2: fast skill learning process - able to see the operation procedure on the displayed overhead checklist in the VR skill learning system. By following the procedure step by step, students could learn and understand where mistakes were made. When the students made operation errors, the system timely reminded them of the error through alarms Theme 3: stress-free learning environment - perceived that because instructors were not present in the VR learning environment, they were able to arrange their own learning progress. Furthermore, the system provides learning resources on demand, thus creating an independent and stress-free learning environment. Theme 4: environmentally friendly students could also repeat the practice process indefinitely, thus considerably saving time (i.e., the student's waiting time to conduct practice), human resources (i.e., teacher supervision), and material resources (i.e., equipment and consumable costs) Theme 5: lacks a sense of reality - participants identified conventional teaching methods portrayed a greater sense of reality. The touch mode of the VR environment did not provide the actual touch sensations that are experienced when practicing and instructor's demonstration is more realistic. The patient's reaction in the VR environment felt artificial and lacked a sense of reality, thus preventing participants from experiencing the warmth of nurse-patient interactions.
Chang & Lai, 2021, Taiwan MMAT: 5	To understand the experience of nursing students in using virtual reality skill learning process.	Qualitative research design	Nursing students (n = 60)	Focus groups, one-hour duration, consisting of 6 × 10 participant groups. Question guide first drafted by the researchers through a literature review. Questions finalized based on their personal teaching experience and the consensus of the research team Content analysis	

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Author/s, Year, Country	Aim	Method/Design	Sample	Outcome Measures	Key Findings
Chang et al., 2022, Taiwan MMAT: 3	To verify the effectiveness of the SVVR-based system for childbirth education	exploratory study using social learning theory. Quasi-experimental design	Nursing students (<i>n</i> = 64)	Six-item learning motivation scale (3 items for intrinsic motivation and 3 for extrinsic motivation) Seven-item learning attitude scale Nine-item learning satisfaction scale Six-item critical thinking disposition scale All instruments used a 5-point Likert rating scheme and had acceptable Cronbach α values, ranging from .79 to .88. A total of three open-ended questions and 20 multiple-choice items related to childbirth common knowledge and skills, giving a perfect score of 100, are concluded. Cronbach α for the assessment reached 0.70, showing acceptable reliability in internal consistency.	Students who adopted the SVVR approach had significantly better effects (Mean = 81.12; SD = 0.41) on their learning achievement than did those who learned with the conventional video-watching approach (Mean = 79.94; SD = 0.74), implying that nursing students who adopted the SVVR approach had higher learning achievement in the childbirth class than those who adopted the conventional learning approach. Students who adopted the SVVR approach had significantly better effects (Mean = 4.33; SD = 0.41) on their learning motivation than did those who learned with the conventional video-watching approach (Mean = 3.87; SD = 0.74), implying that nursing students who adopted the SVVR approach had higher learning motivation in the childbirth class than those who adopted the conventional video-watching approach. Students who adopted the SVVR approach did not have significantly better effects (Mean = 4.68; SD = 0.31) on their learning attitude than did those learning with the conventional video-watching approach (Mean = 4.51; SD = 0.38). The SVVR approach had no significant effects (Mean = 4.20; SD = 0.36) on nursing students' perceptions of critical thinking in comparison with those who learned with the conventional video-watching approach (Mean = 4.13; SD = 0.45) The SVVR approach had significant effects (Mean = 4.70; SD = 0.32) on the nursing students' perceptions of critical thinking in comparison with the conventional video-watching approach (Mean = 4.35; SD = 0.41) SimCARE proved feasible for improving undergraduate nursing students' cross-cultural communication skills SimCARE produced a good level of sense of presence Results also show high usability and satisfaction Participants believed SimCARE allowed them to become aware of cultural differences and gain interest in caring for patients from diverse populations Fidelity was relatively low. Participants who wore glasses experienced discomfort when the HMD put pressure on their glasses
Chae et al., 2023, Korea MMAT: 2	Describe the development of SimCARE and evaluate the feasibility of its use in nursing education	multimethods approach - a quantitative, pilot 1 group post-test design and 4 qualitative focus group interviews	Nursing students (<i>n</i> = 5)	Task difficulty measured using 6 items, developed by the research team, that addressed 6 tasks required to use SimCARE: creating an account, selecting a scenario, starting a VR simulation, talking with a virtual patient, performing a debriefing, and checking the learning history. Responses were scored on a 5-point scale Sense of presence measured using the 15-item Virtual Presence scale using a 7-point scale. Cronbach α was 0.94 Usability measured with the 12-item Perceived Usability scale using a 5-point. The Cronbach α was 0.92. Simulation design measured using the 20-item Korean version of the Simulation Design Scale using a 5-point scale. Cronbach α was 0.91. Satisfaction measured using the 19-item Korean version of the Post Study System Usability Questionnaire using a 7-point scale. Cronbach α was 0.95.	SimCARE proved feasible for improving undergraduate nursing students' cross-cultural communication skills SimCARE produced a good level of sense of presence Results also show high usability and satisfaction Participants believed SimCARE allowed them to become aware of cultural differences and gain interest in caring for patients from diverse populations Fidelity was relatively low. Participants who wore glasses experienced discomfort when the HMD put pressure on their glasses

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Author/s, Year, Country	Aim	Method/Design	Sample	Outcome Measures	Key Findings
Butt, et al., 2018, USA MMAT: 1	Using game-based virtual reality with haptics for skill acquisition	mixed method pilot study	Junior-level undergraduate nursing students (n = 20)	System Usability Survey (SUS) - 10-item scale that provides a high level of face validity by asking for responses on several aspects of system usability, that is, effectiveness, efficiency, and satisfaction. Highly reliable instrument (Cronbach $\alpha = 0.91$), with the addition of an adjective rating scale with a correlation value of $r = 0.822$. Faculty-designed user-reaction survey used in combination with observations of participants while practicing with the VR system, to qualitatively measure subjects' enjoyment, engagement, physical comfort related to the equipment, likelihood to practice, and preference compared with previous experience of practicing the procedure on a task trainer. To establish validity, the survey was reviewed by two SBE experts at the university.	Participants rated overall usability of the VR system in acceptable range (score range, 42.5-92.5 with a mean of 72.5) using the SUS 80% of subjects rating the system either as good or excellent. User agreement on ease of use (90% agreed or highly agreed), confidence using system (80% agreed or highly agreed), and desire to use the system frequently (80% agreed or highly agreed) Frequency comparisons for each of the 24 items on the user-reaction survey revealed agreement that the VR game was fun, engaging, and made subjects lose track of time (100% agreed or strongly agreed on each item). 70% either agreed or strongly agreed that they would be more likely to practice catheter insertion using this game than a task trainer, and 100% agreed that practicing this way will help insert a catheter correctly Practice time significantly greater for subjects using the VR game (mean [M] = 25.3 minutes; standard deviation [SD] = 5.9) when compared with the control group (M = 14.9 minutes; SD = 6.2; t (18) = 3.86; p < .001) Prelicensure students' system usability score was 57 (SD 17.3), or a medium level of usability. Over half of the male students (53%; n = 33) felt the intervention had high usability, whereas female students tended to rate the intervention as having low (35%; n = 79) to medium (53%; n = 93) usability 85% of participants agreed or strongly agreed that practicing catheterization skills in a virtual environment was fun. 79% agreed or strongly agreed that they felt engaged in their own learning, and 70% agreed/strongly agreed that practicing this way motivated them to keep learning. 3% did not enjoy practicing this way Qualitative results - Four main themes emerged: technology glitches, repetitive practice, visualizing germs, and less waste
Breitkreuz, et al., 2021, USA MMAT: 3	1. determine the usability of the second VR-SUCIG and to 2. understand nursing student reactions to this product as well as learning modality.	Mixed-method design	Prelicensure nursing students (n = 300)	System Usability Scale (SUS) - 10-item scale measures effectiveness, efficiency, and satisfaction with computer applications. A coefficient alpha of .92. (Low SUS = 0-33%; Medium SUS = 34%-66%; High SUS = 67%-100%). User Reaction Survey (URS) - user responses to engagement, satisfaction, overall confidence, and perceived impact of the game on learning. Users responded to Likert-style questions on a five-point scale anchored by strongly agree to strongly disagree. The coefficient alpha of the URS in the previous study was 0.83.	Expectation measure results indicated that all tasks fell within the category referred to as "promote it" (89.28% combined test between pilot + final test samples). Participants found tasks easier to perform than expected. SUS indicated system was genuinely useable (70%) Overall satisfaction indicated participants had a positive and satisfying experience (97.61%) The comments that were not so positive were linked to the dizziness and nausea experienced by some students
Botha, et al., 2021, South Africa MMAT: 1	To expand on the existing knowledge by providing insight into South African nursing student experiences while being immersed in a VE where they had to manage a virtual patient with a foreign object in the airway	Pilot study and quantitative design	3rd-year undergraduate nursing students (n = 34)	System Usability Scale (SUS) -10-items, using a five-point Likert scale. After-scenario questionnaire - an evaluation measure with three questions aimed at establishing users' level of agreement with the effectiveness, efficiency, and satisfaction of the system in question, same 7-point Likert scale used Net promoter Score - calculated using the responses to one question, namely 'How likely are you to recommend our system to a friend or colleague?' accompanied by a 10-point Likert scale.	

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Table 3 (Continued)

Author/s, Year, Country	Aim	Method/Design	Sample	Outcome Measures	Key Findings
Adhikari, et al., 2021, Scotland MMAT: 4	To assess the impact of IVR simulation on confidence and anxiety in addition to its acceptability and feasibility with pre-registration nursing students.	A two-stage sequential mixed-methods feasibility study underpinned by gaming theory	3rd year pre-registration nursing students (n = 19)	Pre-post-test using the Nursing Anxiety and Self-Confidence with Clinical Decision-Making Scale (NASC-CDM) - 27 items; 6-point forced-choice Likert-type scale with two subscales: self-confidence and anxiety. Scale has demonstrated validity and internal consistency reliability for each subscale (self-confidence = 0.97; anxiety = 0.96). Informal debrief conducted followed by semi-structured interviews using a topic guide.	A 26% increase in the mean confidence score post intervention and 23.4% decrease in anxiety suggests IVR intervention increase confidence and decreases anxiety when caring for a person with sepsis 4 themes emerged from focus groups - acceptability, applicability, areas of improvement, limitations Participants found IVR game realistic, immersive and interactive Facilitated with knowledge acquisition IVR sepsis game provided them with the opportunity to practice decision-making skills in a safe environment IVR game complimented conventional clinical simulation

while technical skills included paediatric care, decontamination and infection control.

Nontechnical skills. Problem-solving, clinical reasoning and critical thinking were assessed in several studies using VR technology. Two studies measuring problem-solving found increased abilities in the experimental compared to the control group related to neonatal resuscitation (Yang & Oh, 2022) and mental health education (Lee et al., 2022). Clinical reasoning results were mixed, with one study showing significant improvement in the VR group and another finding no significant difference (Lee & Han, 2022; Yang & Oh, 2022). Chang et al. (2022) assessed critical thinking in child-birth education but found no significant differences between the experimental and control groups.

Technical skills. Technical skills were evaluated in three studies and results were mixed. One study, utilizing a self-devised Decontamination Checklist, found improved performance in decontamination skills including personal protective equipment (PPE) use across groups immediately after the intervention. However, there was no significant difference between the VR and other groups and all groups demonstrated a decline in skills at a six-month review (Smith et al., 2018). Another study demonstrated improved infection control practices in the experimental group related assessment and oxygen therapy use, however, there were no differences in focused assessment, medication administration and evaluation skills (Cieslowski et al., 2023). Qualitative findings in a study by Chang et al. (2022) revealed that participants felt that VR assisted their skill development related to nasogastric care, stating "Skill training is easier in VR and it was easier to learn..." and "The VR skill learning system can assist learners who are not yet familiar with the procedures to understand the overall process..."

Self-efficacy and confidence. Three studies measuring self-efficacy identified increases in both experimental and control groups, with greater increases in VR groups in areas such as PPE use (Yu & Yang, 2022), neo-natal high risk infection control (Yu et al., 2021) and mechanical ventilation care (Lee & Han, 2022).

Five studies using varied modalities and technologies evaluated confidence related to decision-making and providing care. Three of these reported increased self-confidence in the VR groups in sepsis and asthma management (Adhikari et al., 2021; Vaughn et al., 2016) and neonatal resuscitation (Yang & Oh, 2022). By contrast, one study found higher confidence levels in the group using 2D video compared to the VR group (Hoyt & Hauze, 2023). Qualitative results also identified that participants felt more confident in-patient care provision after exposure to VR technology with comments such as, "It has given me the confidence knowing that I do know more and I know what to do when situations come up," and "VR not only made the course more interesting ... [it] reinforced knowledge which gives me more confidence" (Adhikari et al., 2021; Chen & Liou, 2022; Hannans et al., 2021).

Motivation. Learner motivation was examined in five studies, each using different VR-based approaches. Three studies employed head-mounted display (HMD) VR technologies (Hoyt & Hauze, 2023; Jung & Park, 2022; Yang & Oh, 2022), while one used spherical video-based virtual reality (SVVR), offering a 360-degree panoramic view (Chang et al., 2022). The fifth study adopted a qualitative exploratory design to investigate how VR could be used to enhance English language learning (Wu et al., 2021). Four of these studies compared motivation levels between experimental and control groups in contexts including childbirth education (Chang et al., 2022), anaphylaxis management (Hoyt & Hauze, 2023), pre- and postoperative care for chemoport insertion (Jung & Park, 2022), and neonatal resuscitation (Yang & Oh, 2022).

Findings were mixed. One study reported significantly higher motivation in the experimental group compared to the control

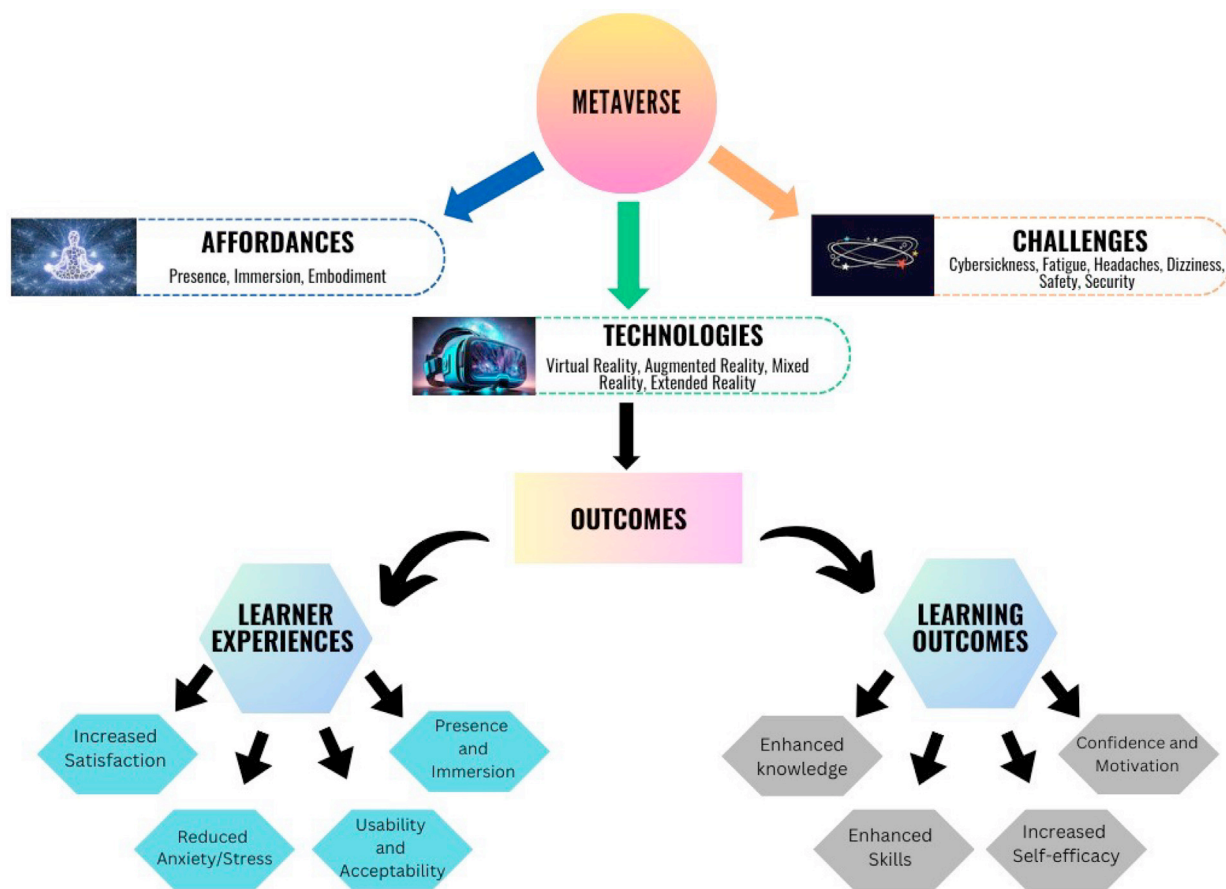


Diagram 1. Visual representation of the metaverse learning outcomes.

group (Chang et al., 2022), while three others found motivation increased in both groups but without significant differences between them. Qualitative results indicated that participants perceived VR as a motivational tool, with its authenticity enhancing learning effectiveness (Wu et al., 2021). One participant noted, “I felt more motivated to learn the new words by exploring the VR system, which was totally different from the boring rote learning method” (Wu et al., 2021).

Learner experiences

Learner satisfaction. Learner satisfaction is defined as the extent to which learners view their educational experiences as positive, fulfilling, and meeting their expectations (Song & Kao, 2023). Satisfaction was the most researched outcome for learner experiences (n = 14 studies). Thirteen of the studies referred to the use of VR HMDs and one used augmented reality (AR). Six studies reported significantly higher satisfaction levels in experimental compared to control groups related to childbirth education (Chang et al., 2022), pre and postoperative care for chemoport insertion (Jung & Park, 2022), mechanical ventilation education (Lee & Han, 2022), mental health education (Lee et al., 2022) and neonatal resuscitation (Yang & Oh, 2022). Studies using single-group post-test designs also showed high levels of learner satisfaction with VR interventions with participants noting that the VR interventions were visually appealing, useful for repetitive learning, and exhibited good instructional design (Botha et al., 2021; Chae et al., 2023; Hoyt & Hauze, 2023; Kim & Ahn, 2021; Lee et al., 2022; Vaughn et al., 2016). Qualitative findings also revealed high levels of satisfaction, with participants finding the interventions novel, enjoyable, interactive, and memorable (Saab et al., 2022). Parti-

cipants in one study stated VR was “a great way to learn” and “interesting” (Farra et al., 2018).

Presence and immersion. Presence is the subjective experience of being transported into a synthetic environment and feeling as if one is there despite being physically located elsewhere (Wang et al., 2017). Immersion refers to the extent of engagement and involvement a user experiences within a virtual environment, often characterized by the perception of being physically present in a nonphysical world (Kim et al., 2017). Seven studies evaluated presence and immersion. Two studies showed significantly higher immersion in the experimental compared to control groups related to mechanical ventilation management (Lee & Han, 2022) and infection control practices (Yu & Yang, 2022), whilst a third study determined higher presence in participants who completed IVR than those who performed the same tasks using a computer (Dang et al., 2018). Two studies identified that participants found the VR intervention created a sense of presence for developing communication skills (Chae et al., 2023) and mass casualty incident management (Paquay et al., 2022). Qualitative data supported these findings, with participants describing VR as realistic and immersive, saying “it felt like being in a real hospital environment” (Botha et al., 2021; Chae et al., 2023).

Usability and acceptability. Usability refers to the ease and efficiency with which users can interact with a system to achieve their goals (International Organization for Standardization, 2018). Eight studies evaluated the usability of Metaverse technologies, with most reporting acceptable to good scores. Three studies recorded high usability ratings, particularly for ease of use in foreign body management (Botha et al., 2021), nursing care related

Table 4
Metaverse Modality and Outcomes.

Learning Outcomes			
Author/s and Country	Focus	Simulation Modality	Outcome/s Measured
Adhikari, et al. (2021), Scotland	Clinical decision making with sepsis identification and management	IVR simulation game	Confidence/anxiety - nursing anxiety and self-confidence in clinical decision making scale (NASC-CDM)* Acceptability - semi-structured interviews
Breitkreuz, et al. (2021), USA	Indwelling catheter (IDC) insertion skills	VR Urinary Catheter Insertion Game (VR-SUCIG)	Usability - System Usability Scale (SUS)* Engagement/satisfaction /confidence - User Reaction Survey (URS)*
Chen & Liou (2022), Taiwan	Obstetric education - natural and caesarean delivery	Spherical video virtual reality - based childbirth learning system	Confidence/communication skills - interviews and feedback forms
Chang et al. (2022)	Obstetric nursing - assessment and care during labour	IVR childbirth simulation using Unity Google VR SDK (Google cardboard) + mobile phone	Critical thinking (CT) - Critical Thinking Disposition Scale* Satisfaction - Learning Satisfaction Scale* Motivation - Learning Motivation Scale* Attitude - Learning Attitude Scale* CT/satisfaction/motivation/attitude - focus groups
Choi (2022), Hong Kong	Simple wound dressing skill	Simulation game in preparing for and completing a simple dressing, comparing nonimmersive desktop simulator (DTS) to IVR (HTC VIVE)	Knowledge - developed by researchers Usability - Simulator Usability Questionnaire (SUQ)* Acceptability - User Acceptance Questionnaire (UAQ)*
Cieslowski et al. (2023), USA	Acute care paediatric management	IVR vs hospital-based training - paediatric asthma simulation	Technical skills - blinded research assistants using an observer checklist Acceptability - focus groups
Hannans et al. (2021), USA	Development of nontechnical skills in client-centred care (knowledge, confidence, communication and empathy) through embodiment of a patient experiencing a health-condition	IVR (Embodied Labs immersive training platform)	Knowledge/confidence/empathy - developed by Embodied Labs and modified and adapted for study.
Hoyt & Hauze (2023), USA	Anaphylaxis assessment and intervention	Written case study vs 2D video vs IVR anaphylaxis case study/simulation	Knowledge - Researcher designed questionnaire Confidence/satisfaction - National League for Nurses Student Satisfaction and Self-Confidence in Learning Scale (NLN-SSSCL)* Motivation - Instructional Materials Motivation Survey Satisfaction (IMMS)*
Jung & Park (2022) Korea	Pre and post operative care of chemo-port insertion surgery	IVR using HMD simulation in virtual angiography room	Knowledge - Researcher developed questionnaire Attitude - Learning Attitude Survey developed by Korea* Educational Development Institute, (n.d.) Motivation - Tool based on IMMS* Satisfaction - Satisfaction Tool developed by Yoo, 2001*
Lau et al. (2023) Singapore	Clinical procedures/skills - Subcutaneous (S/C) insulin injection and Intravenous therapy (IVT) administration	IVR simulation (HMD - Meta Quest) using virtual clinical scenarios to perform procedures	Knowledge Motivation/attention/confidence/satisfaction - Game Perception Scale* Engagement/satisfaction /confidence - URS*
Lee & Han (2022), Korea	Identification and management of mechanical ventilation alarms of patients experiencing acute respiratory distress syndrome (ARDS)	IVR (HMD - Oculus), Virtual simulation of a ventilated patient	Experience of VR - Focus groups Knowledge - researcher developed questionnaire Nontechnical skills - Nurses Clinical Reasoning Scale* Self-efficacy - Scale developed by Ha & Koh (2012)* Satisfaction - Numeral Rating Scale (NRS)* Immersion - Flow Short Scale*
Lee et al. (2022), Korea	Caring for a person experiencing schizophrenia - problem identification and management	360-degree videos delivered via HMDs (Oculus Go)	Knowledge - researcher developed questionnaire Nontechnical skills - problem solving - Korean problem solving process inventory* Satisfaction - questionnaire developed by Kim & Ha (2020)*

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Table 4 (continued)

Learning Outcomes			
Author/s and Country	Focus	Simulation Modality	Outcome/s Measured
Paquay et al. (2022) Belgium	Mass casualty incident management	IVR (MCI-IS - Mass casualty incident immersive simulation) using HDM [HTC Vive]	Presence -PQ* Immersion - ITQ* Decision-making - Rational-Experiential Inventory (REI)* Cybersickness - Simulator Sickness Questionnaire Stress - Mental Readiness Form (MRF)*
Plotzky et al. (2023), Germany	Endotracheal suctioning skill	Comparison of 3 groups - video, VR low (controller-based input and tracking system similar to a video game), immersive VR high (incorporates Oculus hand tracking and input system enabling users to see and interact with their actual hands). Virtual patient simulation used for 2 x VR groups.	Knowledge - researcher developed knowledge test Practical skill - Objective Structured Clinical Examination (OSCE) Satisfaction - Affective-Behavioural-Cognitive-Satisfaction Questionnaire (ABC-SAT)* Acceptability - Virtual Reality Hardware Acceptance Model (VR-HAM)* Experience/learning/advantages/disadvantages/cybersickness -focus groups
Smith et al. (2018), USA	Decontamination skills including donning personal protective equipment	Desktop vs IVR using HMDs (Oculus Rift)	Performance - researcher developed decontamination checklist Knowledge - cognitive exam based on Federal Emergency Management Association (FEMA IS-346) Satisfaction/experience - Focus groups
Traister (2023) USA	Anxiety identification and management and communication skills	IVR using anxious patient scenario by Oxford Medical Simulation.	Participant anxiety levels – short-form State Trait Anxiety Inventory (STAI)* Communication - Oxford Medical Simulation Communication Performance Analytics Board
Yang & Oh (2022), Korea	Neo-natal resuscitation skills/management and knowledge	Comparison between control, simulation and VR groups IVR gamification program - neonatal resuscitation game	Knowledge -Neonatal Resuscitation Nursing Knowledge Measurement Tool* Problem-solving - questionnaire developed by Lee et al., (2008) Clinical reasoning (CR) - Nursing Clinical Reasoning Scale* Confidence - questionnaire developed by Yoo (2013) Motivation - Learning Motivation Test Paper Anxiety - STAI*
Yu & Yang (2022) Korea.	Infection control practices - donning and doffing of personal protective equipment for paediatric respiratory infectious disease patients	IVR (VRICS - Virtual reality Infection Control Simulation)	Knowledge -tool developed by Choi (2016)* Performance -tool developed by Kwon (2021)* Self-efficacy -tool developed by Ayres (2005)* Satisfaction -tool developed by Cho (2018)* Immersion -tool developed by Ching & Yang (2012)*
Yu et al. (2021) Korea	Neonatal infection control skills related to basic care, feeding management, skin care and environmental management	HirNIC VR simulation using HMD (HTC VIVETM)	Knowledge - High-risk Neonatal Infection Control Competency Scale Knowledge (HirNICCS_K)* Self-efficacy - tool based on outcome-present state-test (OPT) model) Satisfaction - tool developed by Cho (2018)
Learner Experiences			
Author/s	Focus	Simulation Modality	Outcome/s measured
Adhikari, et al. (2021), Scotland	Clinical decision making with sepsis identification and management	IVR simulation game	Confidence/anxiety - Nursing Anxiety and Self-Confidence in Clinical Decision Making Scale (NASC-CDM)* Acceptability - Semi-Structured Interviews
Botha, et al. (2021), South Africa	Foreign body diagnostics and management IDC insertion skills	IVR simulation game using the Oculus Rift (HMD) VR Urinary Catheter Insertion Game (VR-SUCIG - VR -)	Satisfaction/usability - System Usability Scale (SUS)* Usability - SUS* Engagement/satisfaction /confidence - User Reaction Survey (URS)*
Breitkreuz, et al. (2021), USA			
Butt, et al. (2018), USA	IDC skills	VR simulation focused on maintaining sterile technique during urinary catheterisation using HMDs (Oculus Rift with sensory gloves)	Usability - SUS* User reaction (faculty designed survey + participant observations)
Chae et al. (2023), Korea	Development of a game called SimCARE to assess problems and identify appropriate solutions of dissatisfaction of nursing care for patients with differing cultural backgrounds	IVR simulation using a Oculus Rift (HMD)	Presence - Virtual Presence Scale* Usability - Perceived Usability Scale* Satisfaction -Post Study System Usability Questionnaire* Feasibility - Focus groups - inductive content analysis

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Table 4 (continued)

Learning Outcomes			
Author/s and Country	Focus	Simulation Modality	Outcome/s Measured
Chang & Lai (2021), Taiwan	Nasogastric tube care skills	IVR nasogastric tube education environment	Satisfaction/presence/usability - focus groups
Chang et al. (2022), Taiwan	Obstetric nursing - assessment and care during labour	IVR childbirth simulation using Unity Google VR SDK (Google cardboard) + mobile phone	Critical thinking (CT) - Critical Thinking Disposition Scale* Satisfaction - Learning Satisfaction Scale* Motivation - Learning Motivation Scale* Attitude - Learning Attitude Scale* CT/satisfaction/motivation/attitude - focus groups
Choi (2019), Hong Kong	Simple wound dressing skill	Simulation game in preparing for and completing a simple dressing, comparing nonimmersive desktop simulator (DTS) to IVR (HTC VIVE)	Knowledge - developed by researchers Usability - Simulator Usability Questionnaire (SUQ)* Acceptability - User Acceptance Questionnaire (UAQ)*
Cieslowski et al. (2023), USA	Acute care paediatric management	IVR vs hospital-based training - paediatric asthma simulation.	Technical skills - blinded research assistants using an observer checklist Acceptability - focus groups
Dang et al. (2018), USA	Postoperative care - 3 part rolling scenario Scenario 1 - Conducting a postoperative assessment Scenario 2 - 24hrs post op (deterioration) Scenario 3 - Maintaining patient stability awaiting transfer to ward Decontamination skills	Traditional simulation vs television (TV) vs VR	Presence - Presence Questionnaire (PQ)* Immersion - Immersive Tendencies Questionnaire (ITQ)*
Farra et al. (2018), USA		Desktop vs written instruction vs IVR - Oculus Rift	Satisfaction/experience/simulation design - focus groups
Hoyt & Hauze (2023), USA	Anaphylaxis assessment and intervention	Written case study vs 2D video vs IVR anaphylaxis case study/simulation	Knowledge - Researcher designed questionnaire Confidence/satisfaction - National League for Nurses Student Satisfaction and Self-Confidence in Learning Scale (NLN-SSSCL)* Motivation - Instructional Materials Motivation Survey Satisfaction (IMMS)*
Jung & Park (2022) Korea	Pre and post operative care of chemo-port insertion surgery	IVR using HMD simulation in virtual angiography room.	Knowledge - Researcher developed questionnaire Attitude - Learning Attitude Survey developed by Korea* Educational Development Institute, (n.d.) Motivation - tool based on IMMS* Satisfaction - Satisfaction Tool developed by Yoo, 2001* Satisfaction -tool developed by Stein, 1997* Learning Effect - Multimedia Learning Effect developed by Kim, 2000*
Kim & Ahn (2021), Korea	Measurement and comparison of nursing students learning effects and learning satisfaction of using IVR	IVR (HMD - HTC VIVE) Rollercoaster Game	Knowledge Motivation/attention/confidence/satisfaction - Game Perception Scale* Engagement/satisfaction /confidence - URS* Experience of VR - Focus groups
Lau et al. (2023) Singapore	Clinical procedures/skills - Subcutaneous (S/C) insulin injection and Intravenous therapy (IVT) administration	IVR simulation (HMD - Meta Quest) using virtual clinical scenarios to perform procedures	Knowledge - Researcher developed questionnaire Nontechnical skills - Nurses Clinical Reasoning Scale* Self-efficacy - Scale developed by Ha & Koh (2012)* Satisfaction - Numeral Rating Scale (NRS)* Immersion - Flow Short Scale*
Lee & Han (2022), Korea	Identification and management of mechanical ventilation alarms of patients experiencing acute respiratory distress syndrome (ARDS)	IVR (HMD - Oculus). Virtual simulation of a ventilated patient	Usability - quantitative rating scale questionnaire*
Lee et al. (2020), Korea	Increase mental health nursing students' treatment competence for patients experiencing schizophrenia	360-degree videos delivered via HMDs (Oculus Go)	Knowledge - researcher developed questionnaire Nontechnical skills - problem solving - Korean problem solving process inventory* Satisfaction - questionnaire developed by Kim & Ha (2020)*
Lee et al. (2022), Korea	Caring for a person experiencing schizophrenia - problem identification and management	360-degree videos delivered via HMDs (Oculus Go)	

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Table 4 (continued)

Learning Outcomes			
Author/s and Country	Focus	Simulation Modality	Outcome/s Measured
Makinen et al. (2023), Finland Paquay et al. (2022) Belgium	Clinical reasoning skills in a resuscitation situation Mass casualty incident management	IVR simulation - urgent life support scenario using HMD (HTC VivePro) IVR (MCI-IS - Mass casualty incident immersive simulation) using HDM (HTC vive)	Usability - SUS* Presence/immersion/skill/judgement - interviews Presence -PQ* Immersion - ITQ* Decision-making - Rational-Experiential Inventory (REI)* Cybersickness - Simulator Sickness Questionnaire Stress - Mental Readiness Form (MRF)*
Park and Kim (2022b) Korea	Examine the effect of instructional design of a VE simulation on students' satisfaction through learning immersion	IVR but not specific on what type or what the simulation was about specifically	Instructional Design - Simulation Design Scale* Satisfaction - Educational Satisfaction Scale in Simulation for Nursing Students* Immersion - Learning Immersion in Simulation Scale*
Plotzky et al. (2023), Germany	Endotracheal suctioning skill	Comparison of 3 groups - video, VR low (controller-based input and tracking system similar to a video game), immersive VR high (incorporates Oculus hand tracking and input system enabling users to see and interact with their actual hands). Virtual patient simulation used for 2 x VR groups	Knowledge - researcher developed knowledge test Practical skill - Objective Structured Clinical Examination (OSCE) Satisfaction - Affective-Behavioral-Cognitive-Satisfaction Questionnaire (ABC-SAT)* Acceptability - Virtual Reality Hardware Acceptance Model (VR-HAM)* Experience/learning/advantages/disadvantages/cybersickness -Focus groups
Saab et al. (2022), Ireland Smith et al. (2018), USA	Testicular examination and identification of testicular disease Decontamination skills including donning personal protective equipment	VR-based serious game - E-MAT (Enhancing Men's Awareness of Testicular Disease) Desktop vs IVR using HMDs (Oculus Rift)	Experience/perceptions/satisfaction -Interviews/focus groups Performance - researcher developed decontamination checklist Knowledge - cognitive exam based on Federal Emergency Management Association (FEMA IS-346) Satisfaction/experience - Focus Groups
Traister (2023) USA	Anxiety identification and management and communication skills	IVR using Anxious Patient Scenario by Oxford Medical Simulation	Participant anxiety levels - Short form State Trait Anxiety Inventory (STAI)* Communication - Oxford medical simulation communication performance analytics board
Vaughn et al. (2016) USA	Assessment of acute respiratory deterioration	Augmented Reality Headset (Google Glasses)	Confidence - Self-confidence in learning scale* Simulation design - simulation design scale*
Wu et al. (2021) China Yu & Yang (2022) Korea.	Operating theatre surgical training (instrument nurse) Infection control practices - donning and doffing of personal protective equipment for paediatric respiratory infectious disease patients	IVR - Modern Operating Room (MOR) IVR (VRICS - Virtual reality Infection Control Simulation)	Perception/attitudes - Attitudinal Questionnaire adapted from MacGill & Hobbs (2008) VR experience -Interviews Knowledge -tool developed by Choi (2016)* Performance -tool developed by Kwon (2021)* Self-efficacy -tool developed by Ayres (2005)* Satisfaction -tool developed by Cho (2018)* Immersion -tool developed by Ching & Yang (2012)*
Yu et al. (2021) Korea	Neonatal infection control skills related to basic care, feeding management, skin care and environmental management	HirNIC VR simulation using HMD (HTC VIVETM)	Knowledge - High-risk Neonatal Infection Control Competency Scale Knowledge (HirNICCS_K)* Self-efficacy - tool based on outcome-present state-test (OPT) model) Satisfaction - tool developed by Cho (2018)

Note. HMD = head-mounted display; IVR = immersive virtual reality; VE = virtual environment

* Validated tool.

to cultural diversity (Chae et al., 2023), and mental health nursing (Lee et al., 2022). Two studies compared usability between experimental and control groups: one found significantly higher usability in the experimental group for wound care (Choi, 2022), while the other reported higher, though not statistically significant, scores for catheterization (Butt et al., 2018).

Qualitative findings on usability varied. Some participants found the systems intuitive, noting, “It was quick to learn what each button does” and “We started playing video games when we were 10, so felt comfortable” (Farra et al., 2018). Others preferred a desktop version over immersive devices, citing faster operation and greater comfort (Choi, 2022). Usability challenges were also reported, including cybersickness, physical discomfort, and lack of tactile feedback (Breitkreuz et al., 2021; Butt et al., 2018; Chae et al., 2023; Choi, 2019; Lee et al., 2020; Makinen et al., 2023; Wu et al., 2021).

Acceptability—the extent to which a product, service, or intervention is perceived as satisfactory and suitable by users (Sekhon et al., 2017)—was examined in three studies, all reporting generally positive results (Adhikari et al., 2021; Choi, 2022; Cieslowski et al., 2023). Participants described VR interventions as realistic, interactive, and immersive. Qualitative feedback reinforced this view, with comments such as, “The game actually, I think, was interactive. You feel like you were part of that particular team in there” and “We could really think things through” (Adhikari et al., 2021; Choi, 2022; Cieslowski et al., 2023) Table 4.

Anxiety and stress reduction. Four studies examined anxiety and stress. Three demonstrated significantly decreased anxiety or stress postintervention with VR, related to IVR in a mass casualty response (Paquay et al., 2022), communication (Traister, 2023; Wu et al., 2021) and neonatal resuscitation (Yang & Oh, 2022).

Discussion

This review sought to examine the utilization, application, and effectiveness of Metaverse technologies in simulation-based learning (SBL) within nursing education. While no studies were found that comprehensively addressed the Metaverse in its full scope, existing literature on component technologies such as virtual reality (VR) and augmented reality (AR) offers valuable insight into current practice and emerging trends. The lack of comprehensive studies points to a broader gap in education research regarding immersive, integrated virtual environments.

The analysis revealed two primary themes: Learning Outcomes and Learner Experiences. Research findings indicate that Metaverse technologies, especially VR applications, demonstrate generally positive effects on fundamental learning metrics including knowledge acquisition, self-efficacy, confidence, and student motivation. These results align with trends observed in other studies, where immersive simulation has been shown to enhance clinical knowledge and engagement (Cho & Kim, 2024; Cook et al., 2011; Jallad & Işık, 2022; Lin et al., 2024).

However, the effects on higher-order cognitive skills such as critical thinking and clinical reasoning were inconsistent. This variability is not unique to nursing; with similar inconsistencies being reported in other disciplines, where factors such as simulation fidelity, instructional design quality, and facilitation effectiveness play significant roles in determining learning outcomes (Popov et al., 2024; Shu & Gu, 2023). These findings indicate that Metaverse technologies should not be viewed as a stand-alone pedagogical innovation—but rather a tool embedded within a thoughtfully designed, outcomes-based curriculum.

Similarly, findings on technical skill acquisition were mixed, contrasting with broader health professions education where VR has demonstrated clear benefits for psychomotor skill development, particularly in procedural training such as surgical training

and ultrasound-guided procedures (Gupta & Mathur, 2025; Jallad & Işık, 2022; Liu et al., 2023; Wang et al., 2024). The divergence in nursing may reflect differences in how VR is integrated into curricula, or the types of technical skills being targeted. Thus, nursing education may benefit from adopting cross-disciplinary insights into how to scaffold and assess skill development through immersive technology.

Learner experiences—including satisfaction, immersion, and usability—were predominantly positive, reflecting previous research across a number of educational domains (Bhardwaj, 2024; Gim et al., 2022; Kaddoura & Al Husseiny, 2023; Salloum et al., 2023; Shu & Gu, 2023). However, significant challenges persist. Cybersickness, limited tactile feedback, and technology fatigue remain substantial barriers to effective implementation (Breitkreuz et al., 2021; Butt et al., 2018; Choi et al., 2022; Makinen et al., 2023; Wu et al., 2021). These usability constraints underscore the importance of integrating human-centered design principles into the development of educational technology.

One critical element of the Metaverse not examined in any of the studies included in this review, is that of social connectedness. No studies investigated multiparticipant, synchronous immersive experiences. Synchronous learning provides opportunities for collaboration between tutors and students whilst actively participating in learning activities, with key advantages of synchronous learning including immediate feedback, increased motivation and responsibility, more in-depth learning, and richer interactions (Racheva, 2018). The lack of nursing-specific research in this area represents a substantial missed opportunity, as the potential of the Metaverse to support not merely individual learning but collective competence development remains largely unexplored in nursing education contexts (Racheva, 2018).

The findings of this review highlight a clear need for rigorous, theory-informed studies that explore not only the effects of Metaverse technologies, but also the underlying mechanisms through which they impact learning processes. Future studies should adopt interdisciplinary approaches, incorporating insights from educational psychology, human-computer interaction, and health pedagogy to develop more comprehensive understandings of these technologies in educational practice.

Research priorities should include examining how Metaverse environments can effectively support interprofessional and collaborative learning, a growing focus in healthcare education that is currently underexplored in nursing-specific Metaverse applications. This may involve exploring synchronous, multiuser simulations that authentically replicate real-world clinical teamwork dynamics, potentially enhancing both technical competencies and crucial nontechnical skills.

Finally, nursing education should actively incorporate lessons from other fields where the Metaverse successfully simulate systems-based practice, ethical dilemmas, or public health emergencies—contexts that require both individual expertise and team-based coordination. By situating future research within these broader educational and professional trends, the nursing discipline can better harness the potential of Metaverse technologies to prepare graduates for the complexities of contemporary healthcare.

Limitations

Several review limitations should be acknowledged. First, most of the included studies were conducted with small, single-site sample groups, which limits the generalizability of the findings to the broader nursing student population. Additionally, the heterogeneity in study designs, Metaverse modalities, and outcome measures makes it challenging to draw definitive conclusions or conduct meta-synthesis. Another limitation is the focus on English-

language studies, which may introduce language bias and exclude relevant research published in other languages.

Conclusion

This review has identified the current state of play with regards to the utilization, application, and effectiveness of the Metaverse, and related components, in simulation-based nursing education. The synthesis of the included studies demonstrated that Metaverse technologies can have a positive impact on learning outcomes and learner experiences. However, more attention to the potential for the Metaverse to create social connectedness, particularly in simulation-based learning, is needed. Further, integration of the Metaverse into simulation-based nursing education provides opportunities for immersive, interactive, and realistic learning environments that go beyond traditional teaching methods. The Metaverse is a virtual environment where users can connect, socialize, work and explore scenarios or 3D immersive spaces with others who are not physically present (Meta, 2022; Park & Kim, 2022b). It enables the construction of collaborative and social learning experiences that assist in promoting teamwork and communication skills (Jovanović & Milosavljević, 2022). Through technologies like VR, AR and other immersive tools, the Metaverse offers a unique platform to engage with complex clinical scenarios.

Future research would be beneficial to address social outcomes of utilizing virtual platforms. These may include studies that identify the type of activity or the nature of interaction that users engage in those platforms (Oh et al., 2023), and what influence they may have on student learning.

Declaration of competing interest

None.

CRediT authorship contribution statement

Carley Jans: Writing – review & editing, Writing – original draft, Visualization, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Cherie Lucas:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Tracy Levett-Jones:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.ecns.2025.101807](https://doi.org/10.1016/j.ecns.2025.101807).

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