Extended Reality (XR) technologies in nursing education: A systematic review

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Abstract

Background: Extended reality (XR), as a learning and teaching method in higher nursing education, has been gradually applied over the years. Despite the increasing adoption of XR technologies in nursing education, there remains limited comprehensive evidence synthesizing their effectiveness across learning outcomes.
Purpose: This review aims to examine the effectiveness of utilizing XR technology in nursing education pedagogy
Methods: A systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Five databases: Cochrane, ProQuest, PubMed, Scopus, and Web of Science were searched using predefined keywords. The PICOS framework guided study selection. Included studies were assessed for quality using the Joanna Briggs Institute (JBI) Critical Appraisal Tools and the Mixed Methods Appraisal Tool (MMAT).
Results:. A total of 17 studies were included, involving 2,403 nursing students. XR interventions, particularly Virtual Reality (VR), were the most commonly used type across studies. These interventions improved students' knowledge, skills, and confidence, including their understanding of the social determinants of health, and were highly satisfying due to their immersive features. However, physical discomfort, such as motion sickness, headaches, and eye strain, was reported. The methodological quality of the included studies ranged from fair to good.
Conclusions: Extended reality, particularly VR-based, has significant positive effects on nursing students. Adverse impacts were also found in the application of this technology in the learning system. Addressing these issues is critical to optimizing the application of XR in nursing education. By integrating XR into nursing curricula, educators potentially foster critical thinking, decision-making, and procedural accuracy-key competencies.

Keywords: digital innovation; extended reality; immersive technology; mixed reality; nursing education

Introduction

The advancement of technology applied in the field of education has undergone significant transformations. Technology-based utilization has been rising, with extensive integration of innovative technologies to facilitate student learning (Chang et al., 2024). Millennials and subsequent generations are generally comfortable using online platforms and electronic devices for educational purposes. Therefore, experts argue that universities should be aware of the Internet's influence on students and adapt their learning processes and implement practices to meet students' expectations (Christodoulou et al., 2015; O'Connor et al., 2017). In addition, the use of electronic devices in education is growing rapidly and is expected to be integral to facilitating knowledge acquisition and fostering students' motivation to learn (Chang et al., 2022; Hardie et al., 2020). Technological advancements have reshaped education, necessitating that universities adapt their teaching methods to align with students' growing use of online platforms and electronic devices, thereby enhancing motivation and learning outcomes.

Extended Reality (XR) is an umbrella term encompassing immersive technologies that integrate physical and virtual environments, including Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) (Drees et al., 2020; Hardie et al., 2020). VR creates a fully computer-generated environment, AR overlays digital elements onto the real world, and MR combines physical and virtual objects that interact in real time, using technologies such as head-mounted displays (HMDs) (Brigham, 2017). As part of XR, virtual reality (VR) has proven to be an invaluable tool in healthcare education, facilitating skill practice and reducing the incidence of medical negligence and errors (Rushton et al., 2020). The utilization of VR for educational purposes offers diverse and immersive learning experiences, allowing students to interact with diverse learning content (Chang et al., 2022). Over the past decade, there has been a concerted effort to integrate this technology into health education, driven by its potential advantages, including scalability, increased motivation, and cost savings (Hu et al., 2025; Moro et al., 2019). However, the application of these technologies in health education did not always result in the expected benefits (Garcia et al., 2025; Hu et al., 2025). Therefore, it is important to ensure that potential advantages translate into better learning (Suh & Prophet, 2018; Zhu et al., 2015). XR technologies, including VR, AR, and MR, offer immersive and cost-effective tools for healthcare education, but their effectiveness depends on their ability to support meaningful improvements in learning.

In healthcare education, MR has been increasingly used for anatomy instruction and for simulating complex surgeries or clinical procedures because it enhances interaction between physical and virtual elements and increases the sense of presence (Zhu et al., 2015). MR simulation is a new educational tool that combines the advantages of virtual reality (VR) and augmented reality (AR) (Kim et al., 2021; Zhu et al., 2015). It can offer an immersive experience that allows students to actively participate in complicated clinical situations and help enhance the learning process. Through interactive three-dimensional environments, MR simulations can improve students' skills, knowledge, and clinical reasoning abilities (Kim et al., 2021).

New learning methods in nursing education are inspired by rapid advances in information technology, including extended reality (Zhao et al., 2022). This technique eliminates the need for live patients while creating immersive, interactive nursing encounters that closely simulate real clinical scenarios. This not only saves valuable time for clinical nursing professionals but also reduces the predictors associated with patient interaction in conventional learning curricula (Choi et al., 2022). Consequently, it addresses the shortage of clinical education resources. Nursing students interact with virtual reality through simulating clinical scenarios in the real world. Using specialized extended reality equipment, such as headsets or sensor-equipped gloves, nursing students can interact with virtual patients, medical equipment, and healthcare environments (Iwanaga et al., 2021). This allows them to practice their clinical skills, make decisions in simulated patient care situations, and study various medical scenarios.

In addition, the interactive nature of virtual reality (VR) enhances the educational process by offering nursing students a more engaging and accessible learning experience (Iwanaga et al., 2021; Liu et al., 2023). Nursing students can enhance their understanding of theoretical concepts and receive hands-on training in a safe, controlled environment using virtual technology. Meanwhile, technologies effectively eliminate the drawbacks of conventional teaching and rigid teaching methodologies, enhance nursing students' scientific enthusiasm, and markedly improve their operational skills (Ahmed et al., 2020). Most recently, VR, MR, and AR have helped nursing students feel more confident. In addition, nursing students' intrinsic drive to learn actively is reinforced by interactive learning (Lange et al., 2020; Liu et al., 2023). This naturally encourages nursing students to explore knowledge independently, increase their sense of commitment to their duties, and enhance their curiosity.

Past studies have examined perceptions and acceptance of technology use in nursing education, including VR, AR, and MR, from a general perspective (Aebersold et al., 2018; Liu et al., 2023; Moon et al., 2024). Recent systematic reviews have also examined MR technologies in nursing education, the effectiveness of immersive VR, and AR applications in healthcare education (Evgenikos et al., 2025; Guillen-aguinaga et al., 2025; Wei et al., 2025). However, existing evidence remains fragmented, as previous reviews (Jannin et al.,2019; Choi et al., 2021) mainly focused on specific XR modalities, limited outcome domains, or broader healthcare populations rather than nursing education specifically. Furthermore, limited evidence has comprehensively synthesized both the strengths and weaknesses of XR implementation, including educational benefits, usability challenges, and potential adverse effects in higher nursing education settings. Therefore, there is a need for a systematic review that integrates and analyzes evidence regarding VR, MR, and AR interventions in higher nursing education. This study aimed to review and synthesize the strengths and weaknesses of XR technologies in higher nursing education to improve teaching and learning strategies ultimately.

Materials and Methods

Design

The systematic review was conducted in accordance

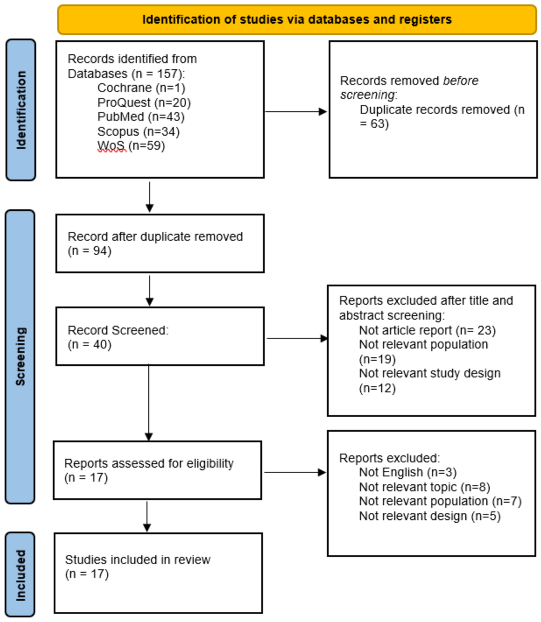

Figure 1. Article selection process: flowchart used in selecting studies using PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses)

with the updated Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2021). The official registration of the review methodology is available in the International Prospective Register of Systematic Reviews (PROSPERO). The study protocol was registered under the identification number CRD42024604595

Search methods

A comprehensive computer-based search was conducted in Cochrane, ProQuest, PubMed, Scopus, and Web of Science up to October 13, 2024. The search aimed to identify studies related to the use of extended reality (XR) technologies in higher nursing education. Search strategy included Medical Subject Headings (MeSH), free terms, and word variations for three primary topics: “extended reality,” “augmented reality,” and “nursing education.” Specific keywords included variations such as “Virtual Reality,” “Reality, Virtual,” “Augmented Reality,” “Mixed Reality,” “Nursing Education,” and “Educational Activities.” Boolean operators (OR/AND) were used to combine these terms systematically to enhance retrieval accuracy. In addition, manual searches of relevant systematic reviews and inspection of reference lists were performed to ensure the comprehensiveness of the findings. The full version of the search strategy can be found in Supplementary Document 1.

Inclusion and exclusion criteria

This study’s criteria were developed following the Population, Intervention, Comparison, Outcome, and Study Design (PICOS) approach to define the key elements of the study (Amir-Behghadami & Janati, 2020). The inclusion criteria were as follows: the population included nursing students at various levels, such as diploma, undergraduate, and graduate programs, while individuals from other majors were excluded. The intervention focuses on the use of extended reality (XR), which includes augmented reality (AR), virtual reality (VR), and mixed reality (MR), integrated into nursing education methods. Comparisons are made against traditional teaching methods, such as lectures, simulations, and hands-on clinical training without the use of XR. The outcomes of interest include measures of clinical competency, knowledge, attitude, skills performance, self-efficacy, and professional identity. Eligible study designs include quantitative, qualitative, and mixed-methods studies. However, non-original research, books, and proceedings are excluded from the criteria.

Data extraction

Two researchers (VA and FT) conducted independent searches for relevant literature and separately selected articles for inclusion and data extraction. Any discrepancies in the selection or extraction process were resolved through discussion or, if necessary, by involving a third party (TP). The screening process adhered closely to the PRISMA guidelines. Initially, articles were excluded based on a thorough review of their titles and abstracts if they clearly did not meet the inclusion criteria. Following a full-text review, some articles initially considered were subsequently excluded. The entire data selection process was managed using Mendeley reference management software.

Quality appraisal

Reviewers (VA and TPH) separately evaluated the risk of bias in each included study using the JBI risk of bias tool for randomized controlled trials (RCTs), quasi-experiments, and cross-sectional studies, as well as the Mixed Methods Appraisal Tool (MMAT). The included studies consisted of 1 randomized controlled trial (RCT), 2 quasi-experimental studies, and 2 cross-sectional studies, while the remaining studies were assessed using the Mixed Methods Appraisal Tool (MMAT). The scoring values are derived from the following percentages: 75% (Good), 50-75% (Fair), and less than 50% (Poor) (Monnaatsie et al., 2021). The quality appraisal results were used to assess the methodological quality of the included studies and were not applied as criteria for study inclusion or exclusion. Discrepancies were resolved through a discussion.

Results

Study Selection

A systematic review identified 157 studies on VR in higher nursing education across five major databases, including Cochrane, ProQuest, PubMed, Scopus, and Web of Science. After removing 63 duplicates, 94 studies were initially screened based on titles and abstracts using the Population, Intervention, Comparison, Outcome, and Study Design (PICOS) criteria. Of these, 54 studies were excluded for non-article reports (23), irrelevant populations (19), and irrelevant study designs (12). The remaining 40 studies underwent full-text screening, and a further 23 were excluded for reasons including non-English language (3), irrelevant topics (8), irrelevant populations (7), and non-relevant designs (5). This rigorous process resulted in 17 studies meeting the inclusion criteria for the final review (Adhikari et al., 2021; Aebersold et al., 2018; Y. Chang et al., 2024; Cheung et al., 2024; Fontenot et al., 2024; Foronda et al., 2018; Hoffman et al., 2023; Jallad et al., 2024; Kiegaldie & Shaw, 2023; Kim & Ahn, 2021; Lee et al., 2020; Moon et al., 2024; Park & Kim, 2022; Plotzky et al., 2023; O'Hare et al., 2020; Yang et al., 2024; Yeo et al., 2024). The study selection process can be found in Figure 1 below.

Study Characteristics

All 17 studies were conducted between 2018 and 2024. A total of 2.403 higher nursing students from undergraduate and graduate programs were involved. The demographic characteristics of study participants were dominated by undergraduate students, who accounted for 16 of 17 studies (94.1%). In terms of study design, the majority of studies employed a Mixed Method Study approach (64.7%) (Adhikari et al., 2021; Aebersold et al., 2018; Y. Chang et al., 2024; Fontenot et al., 2024; Foronda et al., 2018; Hoffman et al., 2023; Kiegaldie & Shaw, 2023; Y. Lee et al., 2020; Plotzky et al., 2023; O'Hare et al., 2020; Yang et al., 2024; Yeo et al., 2024), followed by Quasi-Experiment (17.6%) (Jallad et al., 2024; Moon et al., 2024), Cross-sectional (11.8%) (Kim & Ahn, 2021; Park & Kim, 2022), and only one study applied a randomized controlled trial (RCT) design (5.9%) (Cheung et al., 2024). Geographically, the studies were distributed across several countries, with South Korea contributing the largest proportion (29.4%) (Kim & Ahn, 2021; Lee et al., 2020; Moon et al., 2024; Park & Kim, 2022; Yeo et al., 2024), followed by the United States (23.5%) (Aebersold et al., 2018; Fontenot et al., 2024; Foronda et al., 2018; Hoffman et al., 2023), China (11.8%), and smaller contributions from Scotland (Adhikari et al., 2021), Taiwan (Chang et al., 2024), Palestine (Jallad et al., 2024), Australia (Kiegaldie & Shaw, 2023), Germany (Plotzky et al., 2023), and the United Kingdom (O'Hare et al., 2020) (each at 5.9%).

Regarding the type of XR technology, Virtual Reality (VR) was predominantly used (88.2%) (Adhikari et al., 2021; Aebersold et al., 2018; Chang et al., 2024; Cheung et al., 2024; Fontenot et al., 2024; Foronda et al., 2018; Hoffman et al., 2023; Jallad et al., 2024; Kiegaldie & Shaw, 2023; Kim & Ahn, 2021; Lee et al., 2020; Park & Kim, 2022; Plotzky et al., 2023; Yang et al., 2024; Yeo et al., 2024), with only a small representation from Mixed Reality (MR) (11.8%) (Moon et al., 2024; O'Hare et al., 2020), and no studies applied Augmented Reality (AR). When looking at the type of nursing lessons covered in these studies, Critical and Emergency Care Nursing was the most common focus (41.2%) (Adhikari et al., 2021; Aebersold et al., 2018; Foronda et al., 2018; Moon et al., 2024; Plotzky et al., 2023; O'Hare et al., 2020), followed by Community and Mental Health Nursing (29.4%) (Cheung et al., 2024; Fontenot et al., 2024; Hoffman et al., 2023; Lee et al., 2020; Park & Kim, 2022), Fundamental Nursing (23.5%) (Chang et al., 2024; Jallad et al., 2024; Kiegaldie & Shaw, 2023; Kim & Ahn, 2021; Monnaatsie et al., 2021), and a smaller emphasis on Pediatric Nursing (5.9%) (Yeo et al., 2024). In terms of time duration for XR interventions, 7 studies (41.2%) reported interventions lasting ≤30 minutes (Adhikari et al., 2021; Aebersold et al., 2018; Chang et al., 2024; Jallad et al., 2024; Lee et al., 2020; Plotzky et al., 2023; Yeo et al., 2024), one study (5.9%) reported a duration of 31–60 minutes (Moon et al., 2024), while no studies reported interventions exceeding 60 minutes. However, the duration was not identified (NI) in 9 studies (52.9%) (Cheung et al., 2024; Fontenot et al., 2024; Foronda et al., 2018; Hoffman et al., 2023; Kiegaldie & Shaw, 2023; Kim & Ahn, 2021; Park & Kim, 2022; O'Hare et al., 2020; Yang et al., 2024). Detailed characteristics of the included studies are provided in Supplementary Document 2.

Risk of Bias in Studies

The methodological quality of the 17 studies included in this systematic review was assessed using the Joanna Briggs Institute (JBI) and Mixed Methods Appraisal Tool (MMAT) critical appraisal frameworks. Of the 12 studies evaluated using the MMAT, 88.23%- 94.12% were rated “Good,” indicating high research quality. The remaining 5 studies, evaluated using the JBI framework, were rated as “Fair” (50%-75%), reflecting a moderate level of research quality. The quality appraisal results were used to describe the methodological quality and risk of bias of the included studies and were not applied as criteria for study inclusion or exclusion. Therefore, no studies were excluded based on the JBI or MMAT scores. A detailed summary of the critical evaluations can be found in Supplementary document 3.

Results Synthesis

All included studies were synthesized. Although this review examined extended reality (XR) technologies broadly, most of the included studies focused on virtual reality (VR) interventions, with limited evidence on mixed reality (MR) and no eligible studies investigating augmented reality (AR). Considering both the positive and negative impacts of XR utilization in higher nursing education, the findings are summarized as follows:

The strengths of XR utilization in higher nursing education

Enhanced knowledge and skills

XR significantly improved students’ knowledge and practical skills, such as intravenous injection knowledge (Chang et al., 2024) and NGT placement accuracy (Aebersold et al., 2018). Students experienced significant improvements in clinical judgment, confidence, and self-efficacy after XR-based interventions (Moon et al., 2024; Yang et al., 2024).

Increased engagement and satisfaction

High satisfaction rates and immersive experiences were reported, with XR boosting learning motivation, realism, and student engagement (Jallad et al., 2024; Kim & Ahn, 2021). XR was praised for its cost-effectiveness and realistic simulation environments, making it a valuable supplement for traditional teaching methods (Fontenot et al., 2024; Kiegaldie & Shaw, 2023).

Confidence and emotional resilience

XR increased confidence in clinical practice and stress resilience by providing immersive and engaging scenarios (Adhikari et al., 2021; O’Hare et al., 2020)

The weakness of XR utilization in higher nursing education

Technical and practical limitations

Students reported challenges with image clarity, navigation, and device comfort, which sometimes detracted from the learning experience (Fontenot et al., 2024; Lee et al., 2020). Lack of haptic feedback and fine motor control limited the realism and applicability of XR simulations in some scenarios (Plotzky et al., 2023).

Boundaries in empathy development

Cheung et al., (2024) found that traditional methods outperformed XR in fostering empathy, with narrative videos yielding higher empathy scores. Some participants experienced sensory overload, which reduced emotional connection and hindered their ability to engage fully in immersive settings (O’Hare et al., 2020).

Discussion

This systematic review highlights XR’s potential to enhance students’ knowledge, skill proficiency and confidence. Although this review focused broadly on XR technologies, current evidence in nursing education remains predominantly VR-based, with limited studies examining MR and no eligible AR studies identified. Quantitative results of the included studies showed significant improvements, such as confidence for sepsis care post-intervention (Adhikari et al., 2021) and knowledge of intravenous injection techniques (Chang et al., 2024). Qualitative findings further highlighted XR’s strength in realism, interactivity, and capacity to effectively reinforce learning objectives (Fontenot et al., 2024; Lee et al., 2020). Additionally, MR, with its ability to integrate real-world elements into virtual simulations, provides unique opportunities to simulate collaborative and spatially dynamic clinical scenarios (Moon et al., 2024). These processed findings clearly indicate that XR offers a valuable supplement to traditional higher nursing education methods.

The findings align with Kolb’s experiential learning theory, emphasizing the importance of active and immersive engagement in skill development. As evidenced in previous research, XR enhances student engagement, motivation, critical thinking, and knowledge retention (Logeswaran et al., 2021). Studies have shown that XR complements, rather than replaces, traditional education methods, especially for pre-registration nursing students (Ota et al., 2024). Instructors’ roles in optimizing learner participation in XR-based simulations were also emphasized (Liaw et al., 2021). Additionally, XR-based training, such as training in intravenous therapy using infusion pumps, demonstrated significant improvements in learning motivation, self-efficacy, transfer learning, and performance confidence(Kim & Seo, 2024).

The positive outcome aligns with Kolb’s experiential learning theory, which emphasizes the importance of active, immersive engagement in skill development and posits that change occurs when concrete emotional experiences are integrated with cognitive processes (Lee & Kumar, 2023). VR’s full immersion and MR’s real-time blending of physical and digital environments allow learners to apply theoretical knowledge to practical tasks in a controlled, risk-free setting (Damaševičius & Sidekerskienė, 2024). Furthermore, VR offers a more immersive learning experience, allowing educators to scale their curriculum to make learning more enjoyable (Zhao et al., 2022). The observed improvement in knowledge and confidence demonstrates XR's ability to provide repeatable exposure to important but improbable clinical scenarios to prepare for states of emergency and to access otherwise impossible views of medical procedure (Bracq et al., 2019; Sweller, 2020)

By contrast, this review also highlights the drawbacks of XR, such as motion sickness, cognitive overload, and the lack of haptic feedback for fine motor skill training. Additional limitations less frequently discussed in earlier studies include sensory overload, feelings of isolation during solo VR simulations, and technical constraints such as low image resolution and device discomfort. Broader challenges noted in previous studies include reduced face-to-face communication, high costs, user attitudes, and concerns regarding safety, evaluation, and validation of VR applications (Baniasadi et al., 2020). These issues are particularly relevant for MR applications, where collaborative tasks are often emphasized. The tension between XR's strengths as an innovative educational tool and its limitations highlights the importance of addressing these barriers to maximize its potential in higher nursing education.

According to Cognitive Load Theory (CLT), the challenges in XR utilization stem from the limitations of human cognitive architecture, particularly working and long-term memory (Sweller, 2020; Sweller et al., 2019). XR technologies, including VR and AR are designed to create immersive and interactive learning environments (Bautista et al., 2023; Czok et al., 2023; Huang et al., 2022; Nurjanah & Retnowati, 2024). However, continuous shifts in attention, complex visual stimuli, and the integration of multisensory information can lead to cognitive overload, reducing the efficiency of knowledge retention and skill acquisition(Bautista et al., 2023; Czok et al., 2023; Omobolanle et al., 2024).

Cognitive Load Theory emphasizes the importance of managing three types of cognitive load: intrinsic, extraneous, and germane load (Brunken et al., 2003; Dabor et al., 2019). Intrinsic load refers to the inherent difficulty of the material being learned, while extraneous load arises from poorly designed instructional materials or unnecessary complexity in the learning environment (Bautista et al., 2023; Czok et al., 2023; Omobolanle et al., 2024). Germane load, on the other hand, focuses on optimizing cognitive resources to support learning and schema development (Brunken et al., 2003; Dabor et al., 2019). In XR-based education, excessive extraneous load can arise from poorly designed interfaces, frequent shifts in attention between virtual and real environments, or overly complex visual elements. These issues underscore the need for intentional instructional design strategies that minimize extraneous cognitive load while enhancing germane cognitive load to support meaningful learning outcomes (Jadallah et al., 2024; Omobolanle et al., 2024).

Considering both the strengths and weaknesses of XR utilization in higher nursing education, this review reinforces XR's role in reshaping educational frameworks by integrating immersive and interactive technologies into experiential learning. XR supports critical thinking, decision-making, and procedural accuracy, all of which are essential competencies in nursing practice. Addressing challenges associated with XR use is crucial, including improvements in ergonomics, the incorporation of haptic feedback, and strategies to reduce sensory and cognitive fatigue. Additionally, cost-effective measures are needed to increase XR accessibility, especially in resource-limited institutions. MR holds particular promise for fostering teamwork and communication skills, suggesting its broader application in interprofessional settings.

All the above strengths and weaknesses of XR utilization in higher nursing education are evident; several limitations warrant consideration. First, the included studies were conducted predominantly in developed countries, such as South Korea (5 studies), the United States (4 studies), China (2 studies), Scotland, Taiwan, Australia, Germany, and the United Kingdom (1 for each). This geographical focus limits the generalizability of the findings to broader, particularly resource-constrained, settings. Second, methodological characteristics of the included studies might bias the results; for example, five of 17 included studies were of moderate methodological quality, which might introduce bias. Finally, this review included only studies published in English, due to a lack of translation resources. This limitation may have excluded significant findings from studies published in other languages.

Nursing Implications

The use of XR in nursing education opens up exciting possibilities for how we design our curriculum and help students develop essential skills. Rather than seeing technologies like VR as replacements for traditional teaching methods, such as lectures and hands-on training, we should think of them as valuable tools that can enhance the learning experience. By incorporating XR, nursing programs can offer students safe opportunities to practice in high-pressure situations or rare clinical scenarios, such as managing emergencies or sepsis. This approach not only deepens their knowledge and sharpens their skills, like performing IV injections, but also boosts their overall clinical judgment and confidence.

Importantly, nursing instructors should be mindful of how they design these learning experiences. It is crucial to consider Cognitive Load Theory to ensure that students are not overwhelmed by information or technology. Keeping sessions to about 30 minutes helps prevent fatigue and discomfort, such as motion sickness or eye strain. Additionally, using MR can encourage teamwork and collaboration among students by blending real-world elements into virtual learning. Finally, schools need to tackle the technical and financial challenges that come with these advancements, looking for budget-friendly solutions and improving the comfort of the devices used to ensure that XR-based learning is accessible and successful for everyone.

Limitation of study

This systematic review has several limitations that should be considered when interpreting the findings. First, although the review focused on extended reality (XR) technologies, the available evidence was heavily dominated by virtual reality (VR) interventions, with only a small number of mixed reality (MR) studies and no eligible augmented reality (AR) studies. Consequently, the findings primarily reflect the effectiveness of VR and cannot be generalized to all XR modalities. Second, considerable heterogeneity existed across the included studies regarding study design, educational settings, intervention characteristics, duration of exposure, XR devices, and outcome measures. This methodological diversity precluded quantitative synthesis and limited direct comparisons between studies. Third, most studies were conducted in developed countries, particularly South Korea and the United States, which may limit the transferability of the findings to low- and middle-income countries where technological infrastructure, educational resources, and curriculum implementation differ substantially. Fourth, the methodological quality of the included studies ranged from fair to good, and several studies employed non-randomized or mixed-methods designs, increasing the potential risk of bias. Finally, only English-language publications were included, introducing the possibility of language bias and the omission of relevant evidence published in other languages. Future systematic reviews should include a broader range of languages, examine all XR modalities more evenly, and consider conducting meta-analyses when sufficient homogeneous evidence becomes available.

Conclusions

This systematic review highlights the transformative potential of extended reality (XR), particularly virtual reality (VR) and mixed reality (MR), in higher nursing education. XR technologies effectively enhance nursing students' knowledge, clinical skills, confidence, and engagement by providing immersive and interactive learning environments that complement traditional pedagogical approaches. However, this review also identifies several challenges, including physical discomfort, cognitive overload, limited haptic feedback, and high equipment costs, which may affect user experience and limit widespread implementation. Addressing these challenges is essential to optimizing the integration of XR into higher nursing education. Practical strategies, such as improving device ergonomics, minimizing sensory fatigue, incorporating realistic haptic feedback, and adopting cost-effective implementation approaches, are needed to maximize the educational benefits of XR. By integrating XR into nursing curricula, educators can promote critical thinking, clinical decision-making, and procedural accuracy—key competencies required for contemporary nursing practice. Furthermore, MR's unique capability to facilitate collaborative and dynamic clinical scenarios offers promising opportunities for interprofessional education. Future research should focus on developing evidence-based XR interventions, evaluating their long-term educational effectiveness, and identifying strategies to enhance experiential learning and engagement among nursing students, educators, and technology developers.

Declaration of Interest

Authors declare no competing interests.

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Data Availability

Not applicable

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