Nurse Education Today 155 (2025) 106877

Contents lists available at ScienceDirect

Nurse Education Today

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

Review

Immersive virtual reality in nursing education: A scoping review of components, outcome variables, and interaction modes

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ARTICLE INFO

Keywords:
Immersive virtual reality
Interaction
Nursing education
Virtual patients

ABSTRACT

Background: Immersive virtual reality (IVR)-based nursing education enhances learners' engagement and sense of presence. To optimize learners' experience, it is essential to explore various aspects of IVR-based education.
Objectives: This study aimed to identify the components, outcome variables, and interaction modes, and provide considerations for designing effective IVR-based nursing education.
Methods: This scoping review followed the Joanna Briggs Institute guidelines and explored Academic Search Ultimate, CINAHL, Cochrane Library, Education Source, Embase, ERIC, PubMed, Scopus, and Web of Science. The inclusion criteria were studies involving undergraduate nursing students, virtual patient interactions in IVR, and studies published in English or Korean. The exclusion criteria were studies involving only one-way communication from learners to virtual patients. Outcome variables were categorized using the New World Kirkpatrick Model, and interaction modes were classified based on definitions from previous studies.
Results: Thirty-one studies published since 2021 were included. Virtual patients represented diverse age groups and various health conditions. The scenario settings varied across hospitals, clinics, care facilities, homes, and communities. In all included studies, outcome variables at Level 1 (reaction) or Level 2 (learning) of the New World Kirkpatrick Model were assessed. Controller-based interactions were most frequently utilized, while natural interaction modes, such as speech recognition and gesture-based interactions, were employed in only a few studies.
Conclusions: This review highlights the key aspects of IVR-based nursing education, encompassing diverse virtual humans, scenario settings, outcome variables, and interaction modes. Building on these findings, IVR offers valuable opportunities to enhance learners' engagement and authenticity in nursing education. We suggest that nursing educators carefully consider the components and interaction modes of IVR and employ multiple levels of outcome evaluation when designing educational programs.

1. Introduction

Immersive virtual reality (IVR) has emerged as an innovative pedagogy that provides learners with realistic, multi-sensory experiences. IVR-based education offers a fully immersive, interactive, and realistic simulation environment to enable learners to experience sense of presence in a three-dimensional virtual space through auditory, visual, and kinesthetic modalities (Di Natale et al., 2020; Vogelsang et al., 2024). Head-mounted displays (HMDs) and controllers deliver these stimuli, while tracking of body movements further enhances the sense of realism (Hsieh et al., 2025; INACSL, 2016; Snoswell and Snoswell, 2019). By offering a natural user interface (NUI), IVR facilitates the development of both technical and non-technical skills in nursing students through interactions with virtual patients (VPs) (Xu et al., 2024; Zielke et al., 2017).

To design effective IVR-based nursing education, multiple components need to be considered. Diverse scenarios—including different patient conditions, clinical settings, and virtual humans such as patients, caregivers, and clinical staff—may foster immersion and enhance the cognitive, psychomotor, and affective domains (Bradley et al., 2025; Choi et al., 2022; Park et al., 2024). Pedagogical strategies, such as pre-briefing and debriefing, recommended by the International Nursing

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https://doi.org/10.1016/j.nedt.2025.106877
Received 31 March 2025; Received in revised form 31 August 2025; Accepted 13 September 2025
Available online 22 September 2025

Association for Clinical Simulation and Learning (INACSL), are also crucial for facilitating learners' participation and eventually improving learning outcomes. In particular, debriefing helps learners translate their experiences into clinical contexts through reflective observation and abstract conceptualization (Kolb, 1984; McDermott et al., 2021). These components underscore the need for a systematic approach to outcome variables to verify the effectiveness of IVR-based nursing education.

Evaluating outcomes is therefore critical to establishing the educational value of IVR. Because IVR-based nursing education may influence not only participants but also patients and systems, categorizing outcome variables at the individual and organizational levels provides a broader understanding of educational value (Jeffries et al., 2015; Kim et al., 2024). The New World Kirkpatrick Model (NWKM) categorizes outcomes into four levels: Level 1 (reaction), Level 2 (learning), Level 3 (behavior), and Level 4 (results) (Kirkpatrick and Kirkpatrick, 2016). This model helps clarify how IVR-based nursing education affects satisfaction, learning, behavioral change, patient outcomes, and organizational performance (Alghanaim et al., 2025). While outcome evaluation highlights what learners achieve, an equally important dimension concerns how learners engage with virtual patients during the learning process.

Among technical considerations, interaction modes deserve particular attention. These refer to the methods through which learners manipulate and interact with a virtual environment (Lee et al., 2024; Su et al., 2021). Interaction modes have evolved from the keyboard and mouse interfaces to more natural and intuitive modalities such as gesture-based interaction, speech recognition, and eye-gaze interaction (Deng et al., 2022; Monteiro et al., 2021). By engaging multiple senses, interaction modes allow learners to perform a range of activities and receive meaningful feedback from VPs (Shen, 2021; Li et al., 2019). The effectiveness of IVR-based nursing education largely depends on how dynamically these modes enable interaction between learners and VPs (Kononowicz et al., 2019). Expanding natural interaction through gestures, voice, or facial expressions can further enhance immersion, satisfaction, and learning transfer (Chan et al., 2024; Chen et al., 2025; Xu et al., 2024).

Despite growing evidence, previous studies have not sufficiently addressed several important aspects of IVR-based nursing education. Specifically, descriptions of pedagogical strategies such as pre-briefing and debriefing, the use and effectiveness of diverse interaction modes, and the dimensions of outcome variables have often been limited or inconsistent (Heyn et al., 2023; Ma et al., 2024; Piispanen et al., 2024; Plotzky et al., 2021; Shorey and Ng, 2021; Vogelsang et al., 2024). With technological innovations continuing to enhance presence and immersion through multi-sensory modalities, IVR-based nursing education must be examined from multiple perspectives (Choi et al., 2022; Plotzky et al., 2021; Vogelsang et al., 2024). Exploring these aspects may provide valuable insights for optimizing IVR-based nursing education. Therefore, this study aimed to identify the key aspects of IVR-based nursing education—focusing on components, interaction modes, and outcome variables—leading to the following research questions.

(1) What are the components of IVR-based nursing education?
(2) Which outcome variables have been identified in IVR-based nursing education using virtual patients?
(3) How do nursing students interact with virtual patients in IVR environments?

2. Methods

The Joanna Briggs Institute (JBI) methodology was used for this scoping review (Peters et al., 2024). To ensure quality and reliability, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist, which provides a transparent framework for literature extraction, was used.

2.1. Eligibility criteria

The eligibility criteria were based on the PCC (population, concept, and context) framework (Peters et al., 2024) and comprised studies that (1) included undergraduate nursing students, (2) used VPs in IVR, (3) covered two-way interactions between learners and VPs, (4) included quantitative outcome variables, and (5) were published in English and Korean. Studies were screened according to the definition of IVR that enable learners to experience the presence in a three-dimensional virtual space through multi-sensory modalities using HMDs and controllers (Di Natale et al., 2020; Vogelsang et al., 2024). Studies that employed only one-way communication from learners to VPs (e.g., nursing skill procedures, simple assessments, and watching 3D videos) were excluded. Conference papers, proposals, qualitative studies, and usability or pilot studies with follow-up research were excluded.

2.2. Search strategy and study selection

We conducted a preliminary search on CINAHL, Cochrane Library, Embase, and PubMed to identify the relevant MeSH (medical subject headings) terms and natural-language keywords, which were refined based on a review of prior studies. The final search was conducted across nine databases — Academic Search Ultimate, CINAHL, Cochrane Library, Education Source, Embase, ERIC, PubMed, Scopus, and Web of Science — on July 14, 2025. The search keywords were “immersive virtual reality,” “virtual patients,” “nursing students,” and “nursing education.” The term “interaction” was excluded to allow for more accurate full-text screening. All searches were conducted under the guidance of a research librarian and limited to the titles and abstracts to identify complete scientific papers relevant to the research objective. The search queries were adjusted for each database (Supplementary File 1).

All records were downloaded, and duplicates were removed using EndNote 21 reference management software. After removing duplicates, the remaining records were exported to Microsoft Excel. Two independent reviewers (SN and JS) screened titles, abstracts, and full texts according to the eligibility criteria. Any disagreements were discussed to reach consensus, and when consensus could not be achieved, a third reviewer (HJL) was consulted to make the final decision. In total, disagreements occurred for 11 studies, and after discussion with the third reviewer (HJL), two of these were finally included.

2.3. Data extraction and presentation

A data extraction template was developed to collect the relevant characteristics from the selected studies. Two reviewers (SN and JS) independently extracted data using this template. Then, the extracted data were cross-checked, and any discrepancies were discussed. A third reviewer (HJL) subsequently examined the results, and all the data were finalized based on consensus among all three reviewers. The extraction template included general characteristics of the selected studies, components of IVR-based nursing education, outcome variables, and interaction modes. Several components of IVR-based nursing education were identified by obtaining additional details after reviewing websites offering the programs mentioned in the studies and examining related preliminary studies. The outcome variables were classified according to the NWKM (Kirkpatrick and Kirkpatrick, 2016) across four levels: Level 1 (reaction), Level 2 (learning), Level 3 (behavior), and Level 4 (results). Level 1 refers to learner satisfaction with the educational programs. Level 2 indicates a learner's knowledge acquisition and skills. Level 3 refers to changes in learner behavior or performance. Level 4 represents the improvement in learners' contribution to the organization, reflecting the overall effectiveness of education (Kirkpatrick and Kirkpatrick, 2016).

Interaction modes were categorized based on the definitions to

manipulate and interact with the virtual environment, as identified in previous studies (Lee et al., 2024; Su et al., 2021). These interaction modes include menu-based, speech recognition, point-and-click, controller-based, gesture-based, and learner-facilitator interaction (Bekele and Champion, 2019; Kharoub et al., 2019; Kononowicz et al., 2019) (The explanations of the terms are provided in the Supplementary File 2). Learner-facilitator interaction is not a technological mode but a pedagogical approach through which the educator selects VP responses via keyboard input and provides feedback (Nyathi and Sibanda, 2023). The results of the analysis of the types of interaction modes employed in each study were constructed through graphs with frequencies and percentages.

3. Results

The initial search identified 3688 records across nine databases: Academic Search Ultimate (n = 162), CINAHL (n = 738), Cochrane Library (n = 152), Education Source (n = 203), Embase (n = 568), ERIC (n = 33), PubMed (n = 537), Scopus (n = 749), and Web of Science (n = 546). After removing 2225 duplicates, 1463 records remained and were screened by title and abstract. Of these, 1274 records were excluded, leaving 189 records for full-text review. Following the full-text review, 158 records were excluded for the following reasons: not including undergraduate nursing students (n = 14); not using VPs in IVR (n = 70); not involving two-way interaction between learners and VPs (n = 56); and conference papers, proposals, qualitative studies, and usability or pilot studies with follow-up research (n = 15); not studies in English or Korean (n = 3). Finally, 31 studies were included in the analysis (Fig. 1).

3.1. Study characteristics

Table 1 summarizes the characteristics of the included studies. All studies involving two-way interactions between learners and VPs in IVR nursing education have been published since 2021, highlighting the recent and growing interest in this field. The studies were conducted across 12 countries, most frequently in the United States (n = 8) and South Korea (n = 6). Study designs included quasi-experimental studies (n = 19), randomized controlled trials (n = 2), and mixed-methods

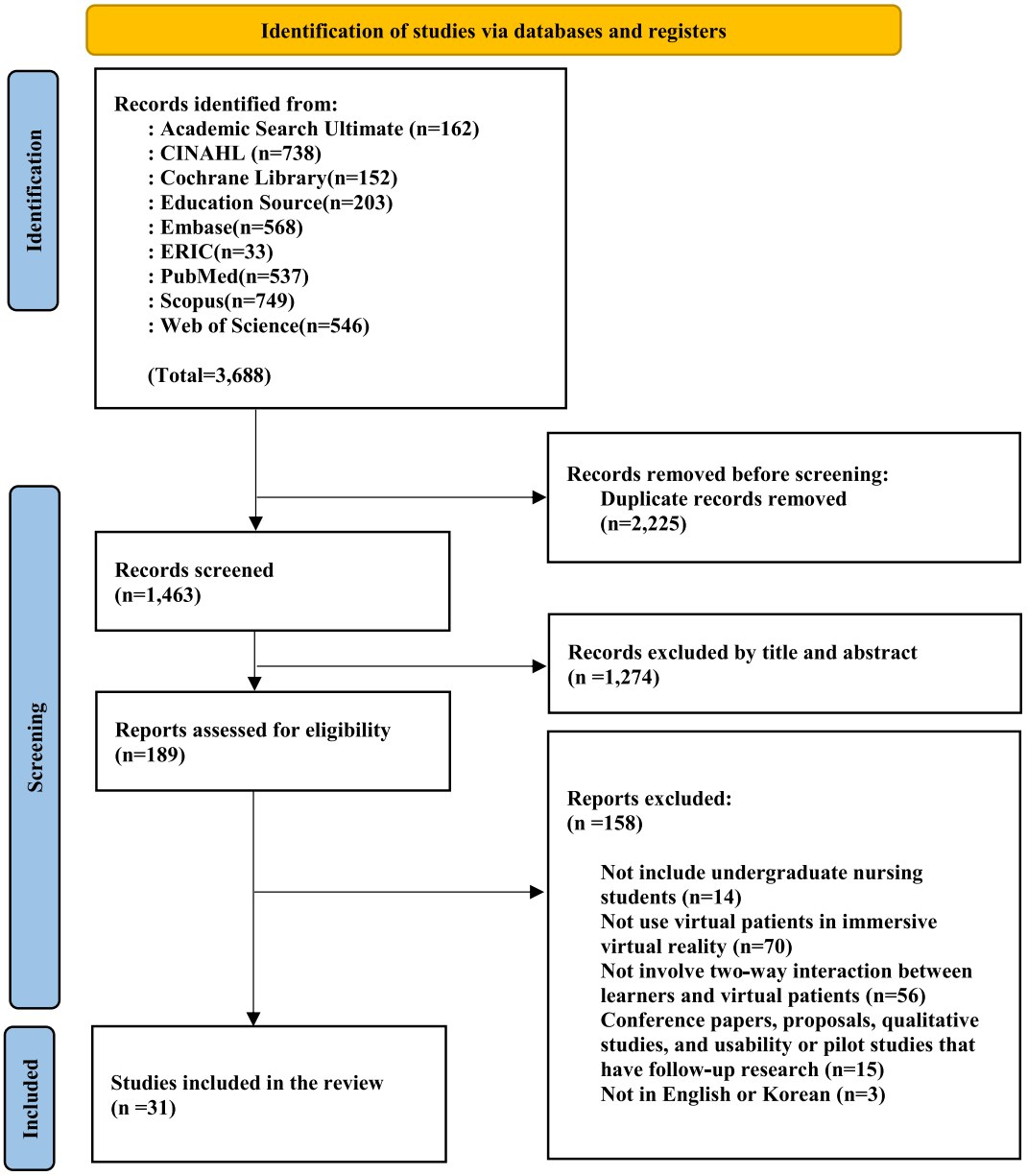

Fig. 1. PRISMA flowchart of studies included in the review.

Table 1
General characteristics and outcome variables of included studies.

Author (year)	Country	Study design	Participants	Sample (n)	Comparison	Outcome variables	Kirkpatrick levels
Yu et al. (2021)	South Korea	Quasi-experimental study	Senior nursing students	51 (CG 25 EG 26)	1) Lectures related to neonatal infection control 2) Clinical practice in a NICU	1) Knowledge 2) Performance self-efficacy 3) Satisfaction	Level 1 Level 2
Botha et al. (2021)	South Africa	Mixed-methods study	3rd nursing students	34 (Pilot test 6 Final test 28)	N/A	1) Expectation measure 2) Usability 3) Promotor 4) Satisfaction 5) Time on task 6) Task completion	Level 1
Hara et al. (2021)	Brazil	Quasi-experimental study	Professors, Nursing students	43 (Professors 13 Students 30)	N/A	Heuristic	Level 1
Havola et al. (2021)	Finland	Quasi-experimental study	Nursing students	40	Screen-based VR simulation	Clinical reasoning skills	Level 2
Ahn and Lee (2021)	South Korea	Quasi-experimental study	3rd nursing students	84 (CG 40 EG 44)	1) Conventional education 2) Academic assignments 3) Utilization of social network system	1) Knowledge 2) Self-confidence 3) Self-efficacy 4) Clinical competency	Level 1 Level 2
Wu et al. (2022)	Taiwan	Quasi-experimental study	3rd nursing students	105 (CG 52 EG 53)	In-person lecture	1) Knowledge 2) VR acceptance 3) VR sickness	Level 1 Level 2
Lee and Han (2022)	South Korea	Quasi-experimental study	4th nursing students	60 (CG 30 EG 30)	Video Lecture	1) Knowledge 2) Self-efficacy 3) Clinical reasoning capacity 4) Learning immersion 5) Learning satisfaction	Level 1 Level 2
Chae et al. (2023)	South Korea	Mixed-methods study	3rd, 4th nursing students	15	N/A	1) Sense of presence 2) Usability 3) Simulation design 4) Satisfaction 5) Task difficulty	Level 1
Azher et al. (2023)	Canada	Quasi-experimental study	3rd nursing students	29 (CG 14 EG 15)	Screen-based VR simulation	1) Usability 2) Performance 3) Cognitive load 4) Emotions	Level 1 Level 2
Traister (2023)	United States	Quasi-experimental study	Nursing students	33	N/A	1) Anxiety level 2) Communication score	Level 1 Level 2
Saab et al. (2023)	Ireland	Mixed-methods study	Nursing and midwifery students	43	N/A	1) Usability 2) Satisfaction	Level 1
Hoffman et al. (2023)	United States	Mixed-methods study	Nursing students	100 (use headset 7 monitor via the screen 93)	N/A	1) Knowledge and objective reflection 2) Impact on learning and confidence	Level 2
Abdalrahim et al. (2023)	Jordan	Mixed-methods study	Nursing students	71	N/A	1) Empathy	Level 1
Savino et al. (2023)	Italy	Quasi-experimental study	Last year medical and nursing students	45 (Medical 7 Nursing 38)	N/A	1) Perceived usefulness 2) Perceived ease-of-use 3) Perceived level of competence	Level 1 Level 2
Lavoie et al. (2024)	Canada	Quasi-experimental study	Nursing students	179 (CG 116 EG 63)	Manikin-based simulation with actor portrayed the role of the mother	1) Engagement 2) Satisfaction 3) Confidence 4) Cognitive load 5) Clinical reasoning	Level 1 Level 2
Bahadur et al. (2024)	Canada	Mixed-methods study	3rd nursing students	239 (CG 187 EG 52)	Screen-based VR simulation	1) Confidence 2) User Engagement 3) Sickness	Level 1 Level 2

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Table 1 (*continued*)

Author (year)	Country	Study design	Participants	Sample (n)	Comparison	Outcome variables	Kirkpatrick levels
						4) Overall satisfaction	
Jeong and Cha (2024)	South Korea	Randomized controlled trial	2nd nursing students	59 (CG 29 EG 30)	Manikin-based simulation	1) Knowledge 2) Satisfaction 3) Self-efficacy 4) Confidence	Level 1 Level 2
Chou et al. (2024)	Taiwan	Randomized controlled trial	2nd nursing students	84 (CG 42 EG 42)	Communication teaching video	1) Communication ability 2) Communication confidence 3) Clinical practice stress 4) Learning satisfaction	Level 1 Level 2
Cieslowski et al. (2024)	United States	Quasi-experimental study	Nursing students	110	N/A	1) Simulation effectiveness	Level 1
Bruce et al. (2024)	United States	Quasi-experimental study	Nursing students	84	N/A	1) Knowledge 2) VR-related usability 3) Simulation effectiveness	Level 1
Vihos et al. (2024)	Canada	Mixed-methods study	2nd nursing students	37	N/A	1) Satisfaction 2) Self-confidence	Level 1 Level 2
Neher et al. (2024)	Switzerland	Quasi-experimental study	Last year medical and nursing students	42 (Medical 21 Nursing 21)	N/A	1) Usability 2) Sickness 3) Sense of presence 4) Subjective workload 5) Satisfaction 6) Technology acceptance scales 7) Handover skills 8) Confidence 9) Perceived Effectiveness 10) Feasibility	Level 1 Level 2
Chan et al. (2024)	Hongkong	Mixed-methods study	Nursing students	202	N/A	1) Virtual non-technical skills 2) Sense of presence 3) Satisfaction 4) Self-confidence	Level 1 Level 2
Yeh et al. (2024)	United States	Quasi-experimental study	Nursing students and Family Nurse Practitioner students	56 (Baccalaureate 34 Family nurse 22)	N/A	1) Knowledge 2) Confidence	Level 2
Hung et al. (2024)	Taiwan	Quasi-experimental study	Nursing students	35	Lecture covering immediate newborn care knowledge and skill demonstration and practice in skill laboratory	1) Knowledge 2) Skill confidence 3) Performance accuracy 4) Time required to complete tasks	Level 1 Level 2
Lavoie et al. (2025)	Canada	Quasi-experimental study	Nursing students	138 (CG 63 EG 75)	Screen-based VR simulation	1) Engagement 2) Satisfaction 3) Confidence 4) Cognitive load 5) Clinical reasoning	Level 1 Level 2
Bradley et al. (2025)	United States	Quasi-experimental study	4th nursing students	237	N/A	1) Knowledge 2) Clinical competence	Level 2
Birdsall et al. (2025)	United States	Mixed-methods study	Prelicensure baccalaureate students and post licensure graduate students	24 (prelicensure baccalaureate students 20 post licensure graduate students 4)	N/A	1) Usability 2) Learning effectiveness 3) Educational use	Level 1 Level 2
Wang et al. (2025)	United States	Quasi-experimental study	Nursing students, gerontological nursing staff members	60 (Nursing students 15 Gerontological nursing staff members 45)	N/A	1) Simulation sickness 2) System usability 3) User experience 4) Motivation 5) Cognitive workload	Level 1

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Table 1 (*continued*)

Author (year)	Country	Study design	Participants	Sample (n)	Comparison	Outcome variables	Kirkpatrick levels
Chang et al. (2025)	Taiwan	Mixed-methods study	3rd nursing students	107 (CG 60 EG 47)	Lecture on infection control theory and skills Practice donning and doffing PPE	1) Knowledge 2) Motivation 3) Attitude	Level 1 Level 2
Hong et al. (2025)	South Korea	Quasi-experimental study	3rd nursing students	41 (CG 20 EG 21)	Online session about childbirth nursing and High-fidelity simulation	1) Childbirth nursing care knowledge 2) Problem-solving ability 3) Nursing performance 4) Learning satisfaction	Level 1 Level 2

Note. CG = Control group; EG = Experimental group; N/A = Not applicable; NICU=Neonatal intensive care unit; PPE = Personal protective equipment; VR = Virtual reality.

studies ($n = 10$). Sample sizes ranged from 15 to 239 participants. Most studies exclusively targeted undergraduate nursing students; however, in seven studies, other groups were also included, such as medical students, midwifery students, graduate students, nursing staff, and professors. Fourteen studies incorporated a comparison intervention. These included traditional methods such as in-person or video lectures, online modules, and assignments, as well as clinical practice and nursing skills training. Some studies directly compared IVR-based nursing education with other simulation modalities, including manikin-based simulation and screen-based VR (Azher et al., 2023; Bahadur et al., 2024; Havola et al., 2021; Jeong and Cha, 2024; Lavoie et al., 2025; Lavoie et al., 2024).

3.2. Aspects of IVR-based nursing education

3.2.1. Components of IVR-based nursing education

Table 2 shows the components of IVR-based nursing education. The included studies utilized various clinical conditions, ranging from neonatal and pediatric disorders to maternal care, infectious and respiratory diseases, cardiovascular and neurological conditions, mental health issues such as suicide risk, and geriatric or chronic care. Several studies also developed scenarios to enhance cultural competence or to manage multiple patients simultaneously (Bradley et al., 2025; Chae et al., 2023; Hoffman et al., 2023). Scenarios were implemented in various settings: hospital wards, emergency rooms, intensive care units, neonatal intensive care units, clinic rooms, care home/senior-care facilities, and delivery rooms. Some programs combined settings, such as wards with ICUs or delivery rooms with wards. VPs represented a wide range of age groups, including older adults, adults, adolescents, pediatric patients, and pregnant women. Twelve studies included other virtual humans such as caregivers or clinical staff, and in one study, the facilitator played the role of a virtual mother (Lavoie et al., 2024).

Pre-briefing sessions were conducted in 28 studies, although six limited these sessions to equipment orientation only. Among them, ten studies provided structured materials such as lectures, videos, or handouts, and in six studies pre-briefing occurred one week before the VR session. The length of pre-briefing sessions varied substantially, ranging from 5 min to 220 min. Debriefing sessions were reported in 21 studies, ranging from 10 to 100 min in length, and typically included self-reflection and feedback. The length of the VR sessions themselves ranged from as short as 6 min to not specifically limited, with three studies repeating the VR experience at least twice (Chou et al., 2024; Jeong and Cha, 2024; Traister, 2023). Most studies used HMDs such as Oculus, HTC Vive, Vive Pro, or Meta Quest, with handheld controllers. One study employed a Leap Motion controller for gesture recognition (Yu et al., 2021), and five studies did not clearly report the device used.

3.2.2. Outcome variables

A variety of outcome variables were measured to evaluate the effectiveness of IVR-based nursing education (Table 1). According to the NWKM, eight studies assessed Level 1 (Reaction), four studies Level 2 (Learning), and 19 studies both Level 1 and 2. None of the included studies assessed Level 3 (Behavior) or Level 4 (Results). For Level 1 outcomes, the most frequently measured variables were satisfaction ($n = 14$) and usability or perceived usefulness ($n = 10$). Other commonly assessed measures included cognitive load ($n = 5$), learning immersion ($n = 4$), simulation effectiveness (n = 4), and VR sickness (n = 4). For Level 2 outcomes, confidence ($n = 12$) and knowledge (n = 12) were most frequently evaluated, followed by clinical reasoning skills (n = 4), self-efficacy (n = 4), and competence ($n = 3$) or performance (n = 3).

3.2.3. Interaction modes

Table 2 and Fig. 2 present the interaction modes used in IVR-based nursing education. Controller-based interaction was the most common ($n = 18$), followed by menu-based ($n = 9$), point-and-click ($n = 8$), speech recognition (n = 3), and gesture-based (n = 1). In five studies, the use of controllers was not clearly specified. Seven studies employed a facilitator-driven method, in which the educator selected VP responses via keyboard input and provided feedback; these were categorized as learner-facilitator interaction. Birdsall et al. (2025) attempted speech recognition, but the function was not fully operational due to technical issues.

Interaction modes were further classified as either unimodal or multimodal. Fifteen studies adopted unimodal interaction, most often controller-based (n = 8), followed by point-and-click (n = 3), learner-facilitator ($n = 2$), and gesture-based (n = 1). Multimodal interactions, combining two or more methods, were observed in sixteen studies. The most frequent combinations were menu-based plus controller-based (n = 5) and controller-based plus learner–facilitator (n = 4). Less common were menu-based plus point-and-click (n = 2) and point-and-click plus controller-based (n = 1). A combination of three modes, menu-based, speech recognition, and point-and-click interactions, was utilized in two studies. The interaction mode could not be clearly categorized in three studies (one unimodal, two multimodal).

4. Discussion

This scoping review explored 31 studies to identify the components, outcome variables, and interaction modes of IVR-based nursing education. The findings highlight both the promise and current limitations of IVR as a pedagogical approach in nursing. While IVR has been adopted internationally and demonstrates potential to enhance engagement, realism, and skill acquisition, the review also reveals gaps in scenario design, pedagogical strategies, outcome evaluation, and interaction modes that must be addressed to realize its educational value.

Table 2
Aspects of immersive virtual reality-based nursing education.

Author (year)	Scenario (setting)	Virtual Human	Pre-briefing (length)	Debriefing (length)	Length	Equipment	Interaction modes
Yu et al. (2021)	1) A premature infant transferred from the delivery room required basic care 2) A premature infant necessary to breastfeed through a gastric tube 3) A full-term infant with rotavirus infection and diarrhea (NICU)	Patient	Orientation to the equipment, Introduction of scenarios (30 min)	Reflection and feedback (20 min)	30–45 min/person (10–15 min/scenario)	Vive Pro Full-Kit, Leap Motion controllers	Gesture-based
Botha et al. (2021)	A 28-year-old female suffering from foreign body aspiration (Ward)	Patient	Conducted without detailed description (not reported)	N/A	20 min/person	Oculus Rift, controllers	Controller-based
Hara et al. (2021)	A senior man with infection; unsuccessful venipuncture (Ward)	Patient	Orientation to the equipment, Introduction of learning objectives and scenario (Not reported)	N/A	The program ends if the learning objectives are met or based on instructor's judgment.	Oculus Rift (Controller use was not specified)	Learner-facilitator
Havola et al. (2021)	A senior patient suffering from chest pain (Ward and ICU)	Patient	Orientation to the equipment (not limited)	N/A	Not reported	HTC Vive Pro-version, controllers	Menu-based, Point-and-click
Ahn and Lee (2021)	1) A patient with hypertension 2) A patient with diabetes mellitus 3) A patient with stroke (Home)	Patient	Orientation to the equipment (Not reported)	Conducted using recorded video (Not reported)	33–45 min/person (8–20 min/scenario)	HTC Vive, controllers	Menu-based, Controller-based
Wu et al. (2022)	A pediatric seizure management (Ward)	Patient, Caregiver (Mother)	Received pre-class reading paper 1 week before, Orientation to the equipment (20 min)	3-phase (description, analysis, application) session (30 min)	10–15 min/person	Oculus Rift S, (Controller use was not specified)	Speech recognition (Whether the interaction was gesture-based or controller-based remains unclear)
Lee and Han (2022)	A patient diagnosed with ARDS, as a complication of confirmed coronavirus (ICU)	Patient	Video lecture (20 min), Orientation to the equipment (5 min)	Checking the contents of nursing performance (20 min)	15 min/person	Oculus goggles (Controller use was not specified)	Whether the interaction was gesture-based or controller-based remains unclear
Chae et al. (2023)	A western man with different expectations of nursing care (Ward)	Patient	Orientation to the equipment, Introduction of scenario (20 min)	Self-guided reflection on action (15 min)	10–15 min/person	Oculus Rift S, Controllers	Menu-based, Point-and-click
Azher et al. (2023)	A senior patient with acute anxiety (ER)	Patient, Clinical staff	Orientation to the equipment (Not reported)	N/A	Not reported	Oculus Quest 2, Controllers	Menu-based, Controller-based
Traister (2023)	An anxious patient (ER)	Patient	Orientation to the equipment (Not reported)	N/A	15–20 min/person, with 2 repetitions between 21–37 days	Headset, Controllers	Menu-based, Controller-based
Saab et al. (2023)	1) Acute severe asthma (28 y) 2) Urosepsis and delirium (78 y) 3) Diabetic ketoacidosis (28 y) 4) COPD and community-acquired pneumonia (80 y) 5) Alcohol withdrawal with suicidal ideation (40 y) → Select one scenario (not reported)	Patient (Clinical staff depending on the scenarios)	N/A	N/A	20 min/person	Headset, Controllers	Menu-based, Controller-based
Hoffman et al. (2023)	A 70-year-old Bangladeshi man with a history of hypertension, depression, and anxiety attended a wellness and flu clinic held at a local mosque	Patient	Orientation to the equipment, Introduction of learning objectives and scenario (not reported)	Debriefing on the 3-phase (reaction, analysis, consolidation) (not reported)	Not reported	Oculus Quest2, Controllers	Controller-based, Learner-facilitator

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Table 2 (*continued*)

Author (year)	Scenario (setting)	Virtual Human	Pre-briefing (length)	Debriefing (length)	Length	Equipment	Interaction modes
	(Asian-American community)						
Abdalrahim et al. (2023)	A patient with dementia (Care home)	Patient	Orientation to the equipment, Introduction of scenarios (not reported)	N/A	Not reported	Oculus Rift, controllers	Controller-based
Savino et al. (2023)	1) An infant with status epilepticus 2) A child with anaphylaxis (ER)	Patient, Mother, Nurse, Respiratory therapist	Orientation to the equipment (15 min)	A facilitator-centered debriefing, Rerunning learned knowledge (not reported)	Not reported	Oculus Quest 2, Controllers	Point-and-click
Lavoie et al. (2024)	A 6-month-old child diagnosed with cystic fibrosis (Clinic room)	Patient (The facilitator played the role of the mother)	Lectures, readings, and simulation materials provided at 1 week before, Orientation to the equipment, Introduction of scenarios (5 min)	Debriefing based on reaction, description, analysis, and application structure (15 min/session, 3 sessions)	30 min/person (10 min/session, 3 sessions)	Oculus Rift, controllers	Learner-facilitator, Controller-based
Bahadur et al. (2024)	1) A patient with acute suicide risk 2) A patient with chronic suicide risk (Not reported)	Patient, Preceptor	Orientation to the equipment, Conducted without detailed description (Not reported)	Debriefing using promoting excellence and reflective learning in simulation (Not reported)	Not reported	Meta Quest, controllers	Point-and-click
Jeong and Cha (2024)	Normal vaginal delivery care during the first to fourth stages of labor (Delivery room and Ward)	Charge nurse, Patients (Woman in labor, Newborn)	Orientation to the equipment, Pre-learning for delivery care (120 min)	Watching recorded videos, self-assessment, and debriefing (90 min)	Conducted at least twice (Not reported)	Oculus Quest 2, controllers	Point-and-click, Controller-based
Chou et al. (2024)	A senior woman whose right limb had become even weaker (Ward)	Patient	N/A	Reflection using recorded videos and generated scores (not reported)	30 min/person, with 4 repetitions for 2 weeks (twice a week)	HTC Vive Focus 3 VR, Controllers	Menu-based, Speech recognition Point-and-click
Cieslowski et al. (2024)	1) An adolescent patient admitted with diabetes who experienced a hyperglycemic episode 2) A geriatric patient with COPD experiencing acute respiratory failure 3) A patient experiencing an anaphylactic reaction to an intravenous antibiotic (Not reported)	Patient, Caregiver	Orientation to the equipment, Conducted without detailed description (10–20 min/scenario)	Conducted without detailed description (20–30 min/scenario)	45 min/person (10–20 min/scenario)	Oculus Quest, Controllers	Controller-based
Bruce et al. (2024)	A client with a history of major depressive disorder and alcohol abuse who expressed suicidal intent and a specific plan (Not reported)	Patient	Orientation to the equipment, Prework training for the Suicide Severity Rating Scale (Not reported)	Allowing for immediate and detailed feedback during debriefing (Not reported)	10 min/person	Headset (Controller use was not specified)	Learner-facilitator
Vihos et al. (2024)	A patient experiencing postoperative respiratory distress (Not reported)	Patient	Orientation to the equipment, Introduction of scenarios (Not reported)	Conducted without detailed description (30–40 min)	20 min/person	Meta Quest 2, controllers	Controller-based, Learner-facilitator
Neher et al. (2024)	A 56-year-old patient with a thunderclap headache and subtle neurological findings and then progressing to a generalized tonic-clonic epileptic seizure due to subarachnoid hemorrhage (ER)	Patient	*E*-learning on best practices for managing epileptic seizures and doctor-nurse handovers provided 1 week before, Orientation to the equipment (Not reported)	Conducted following the 3D Model of Debriefing and included 4 subjects (defusing, discovering, handover, and deepening) (30 min)	23 min/team	Meta Quest 2, controllers	Controller-based, Learner-facilitator
Chan et al. (2024)	1) Clinical practicum orientation 2) Managing multiple tasks 3) Prevention of errors (ward)	Patient, Ward staff	Orientation to the equipment, Introduction of scenarios (30 min)	Conducted without detailed description (Not reported)	30 min/person (10 min/scenario)	Headset, controllers	Menu-based, Point-and-click, speech recognition
Yeh et al. (2024)	A patient with substance use disorders (Clinic room)	Patient	Orientation to the equipment, Introduction of scenarios (Not reported)	Discussion of therapeutic communication and sharing students' experiences with the VR simulation (Not reported)	Not reported	Meta Quest 2 (Controller use was not specified)	Learner-facilitator (Whether the interaction was gesture-based or controller-based remains unclear)

(*continued on next page*)

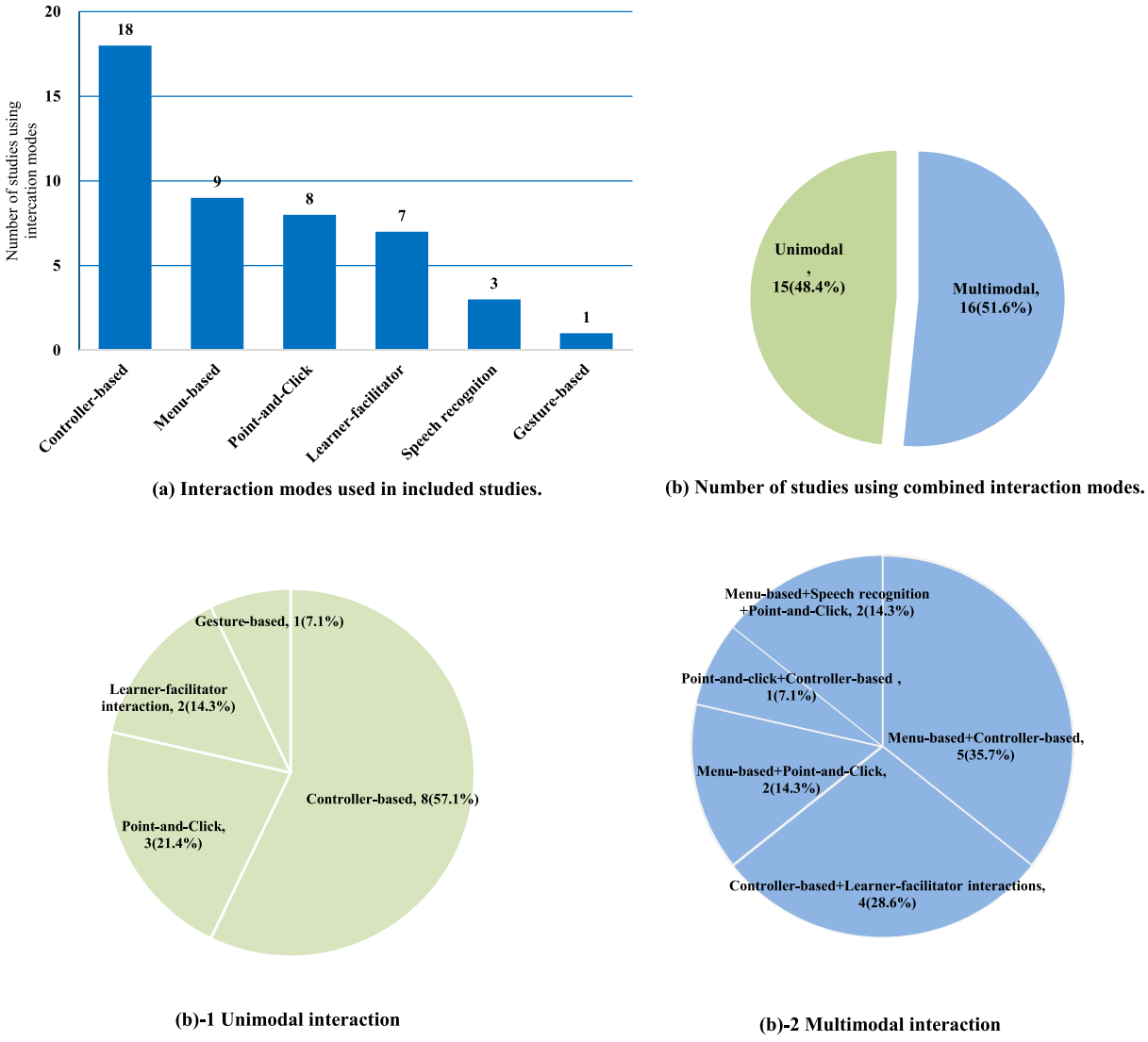
Table 2 (*continued*)

Author (year)	Scenario (setting)	Virtual Human	Pre-briefing (length)	Debriefing (length)	Length	Equipment	Interaction modes
Hung et al. (2024)	Spontaneous vaginal delivery (Delivery room)	Patients (Woman in labor, Newborn)	Lecture covering immediate newborn care knowledge and skill demonstration (60 min)	N/A	On average 10.3 min/person (Varying by individual)	HTC headsets, Controllers	Controller-based
Lavoie et al. (2025)	A 67-year-old widower recently discharged from the hospital following an acute coronary syndrome (Home)	Patient	Lectures, readings, and simulation materials provided at 1 week before, Orientation to the equipment, Introduction of scenarios (5 min)	Debriefing based on reaction, description, analysis, and application (20 min/phase, 3 phases)	10 min/phase (3 phases)	Oculus Rift, Controllers	Controller-based
Bradley et al. (2025)	1) A patient with pyelonephritis 2) A patient with diabetic ketoacidosis 3) A patient with urosepsis 4) Preparing to discharge Patient 1 while caring for Patients 2 and 3 and admitting a fourth patient experiencing hyperkalemia 5) Caring for Patients 2, 3, and 4 while admitting two new patients; one was experiencing chest pain, and the other demonstrated symptoms of respiratory distress (Not reported)	Patient	Orientation to the equipment (Not reported)	Discussion of the initial plan for prioritizing care, nursing care and cognitive skills and applying clinical practice (Not reported)	Not reported	Meta Quest 2, controllers	Menu-based, Controller-based
Birdsall et al. (2025)	A postpartum female client with her baby visiting a health practitioner for evaluation (Clinic room)	Patients (Postpartum female and her baby)	N/A	N/A	20-30 min/person	Meta Quest 2, controllers	Point-and-click (Speech recognition was available but not used due to technical issues)
Wang et al. (2025)	1) An elderly man vital sign checking, body care and environmental cleanliness (Home) 2) An elderly man transport assistance and end of life care (Senior-care facility)	Patient, Family	Orientation to the equipment (Not reported)	N/A	Depending on the number of rounds of scenario	Oculus Quest 2, Controllers	Controller-based
Chang et al. (2025)	A patient with coronavirus in the negative pressure unit (Ward)	Patient	Lecture on infection control theory and skills and online videos of VR operation 1 week before (100 min), Orientation to the equipment (5 min)	Sharing reflections on the VRS program (10 min)	6–8 min/person	Oculus Quest, Controllers	Controller-based
Hong et al. (2025)	A 35-year-old woman experiencing her first pregnancy (Delivery room)	Patients (Woman in labor, Newborn)	Orientation and prerequisite learning (100 min), Lecture Online session about childbirth nursing 1 week before (120 min)	Debriefing using recorded videos, discussing nursing actions, sharing experiences, and providing feedback. (100 min)	Not reported	Oculus, controllers	Controller-based

Note. ARDS = Acute respiratory distress syndrome; COPD = Chronic obstructive pulmonary disease; ER = Emergency room; ICU = Intensive care unit; N/A = Not applicable; NICU = Neonatal intensive care unit; VR = Virtual reality.

The 31 studies included in this review were published after 2021. Although the use of HMDs for IVR has been ongoing since 2018, programs that emphasize narrative creation through VP interactions rather than merely focusing on nursing skill procedures, simple sequences, and instructions were identified only after 2021 (Choi et al., 2022; Fealy et al., 2019; Koskinen et al., 2024; Park et al., 2024). These studies were conducted across various countries, reflecting the global uptake of virtual reality-based education. Such approaches have been widely adopted because of their capacity to enhance abstract reasoning, creativity, empathy, and skills that are challenging to cultivate through traditional educational methods (Au and Lee, 2017; Kuna et al., 2023). This shift underscores a paradigm change in nursing education, from procedure-oriented training toward immersive experiences that dynamically interact with virtual humans under various conditions, fostering not only technical skills but also non-technical skills, such as empathy, communication, and teamwork.

The scenarios in the included studies reflected diverse clinical conditions, patient populations, and care settings, which can increase learner engagement and promote active participation (Choi et al., 2022). This limits opportunities for learners to practice decision-making in complex and unpredictable contexts, such as managing multiple patients, responding to disasters, or providing culturally competent care



(a) Interaction modes used in included studies.

(b) Number of studies using combined interaction modes.

(b)-1 Unimodal interaction

(b)-2 Multimodal interaction

Fig. 2. Interaction modes within IVR-based nursing education.

(Baysal et al., 2024; Bradley et al., 2025; Shujuan et al., 2022). Developing scenarios that incorporate such complexity would allow IVR to move beyond procedural training toward fostering higher-order competencies, including empathy, teamwork, and communication.

Some studies have used pre-briefing and debriefing as pedagogical strategies, whereas these were often limited to equipment orientation, lacked systematic design, and were insufficiently described. Redesigning these strategies to ensure psychological safety, learner engagement, and knowledge transfer is essential (Badowski and Wells-Beede, 2022). Facilitators, in particular, play a pivotal role in bridging virtual experiences to real-world clinical practices, underscoring the need for clear pedagogical frameworks tailored to IVR-based education.

Regarding outcomes, all studies evaluated Level 1 (reaction) and Level 2 (learning) of the NWKM, while none addressed Level 3 (behavior) or Level 4 (results). This narrow focus reflects a missed opportunity to demonstrate the long-term educational and organizational value of IVR. Likewise, previous reviews have indicated that Level 3 is infrequently reported, and Level 4 evidence is nearly absent (Phillips et al., 2023; Strojny and Dużmańska-Misiarczyk, 2023). Evaluating higher-level outcomes, such as changes in clinical performance, patient safety, or healthcare efficiency, is essential to substantiate the relevance of IVR beyond individual learners. Assessing Levels 3 and 4 can also demonstrate organizational impacts and the value of professional development in healthcare systems, thereby supporting wider adoption and sustainable utilization (Phillips et al., 2023; Strojny and Dużmańska-Misiarczyk, 2023). Attention to these higher-level outcomes could shift IVR-based nursing education from being regarded as a limited tool for individual learning to an integrated educational paradigm with institutional and organizational validity.

Interaction modes in IVR-based nursing education have shown progress but remain limited in scope. Although most studies used controller-based methods, few employed natural modalities such as gesture- or speech-based interactions. Natural interactions can strengthen emotional engagement with VPs, facilitate multi-sensory learning, and promote long-term retention (Rakkolainen et al., 2021; Su et al., 2021; Tyng et al., 2017; Xu et al., 2024). In addition, incorporating natural interactions extends the educational impact of IVR by fostering competences that are indispensable in real-world nursing practice. These interactions mirror the authentic ways nurses engage with patients and colleagues in clinical settings, thereby strengthening essential skills such as empathy, therapeutic communication, cultural sensitivity, and teamwork (Chae et al., 2023; Lehmann et al., 2025; Xu et al., 2024). By enabling learners to practice these competences in a safe yet immersive virtual environment, natural interactions bridge the gap between technical skill acquisition and the development of holistic, patient-centered care capacities that are critical in contemporary

healthcare practice. Therefore, nursing educators should view natural and multimodal interaction modes as core pedagogical considerations rather than supplementary features.

4.1. Implications

Although the introduction of IVR has brought a paradigm shift in nursing education, the current status of IVR-based nursing education remains exploratory, with important gaps that require further development. To optimize its educational value, nursing educators should design more sophisticated and engaging scenarios that incorporate diverse patients, complex clinical challenges, and nonlinear narratives. Additionally, there is a clear need to develop pre-briefing and debriefing strategies tailored specifically to IVR-based nursing education. Such considerations can provide a structured framework that advances nursing education, improves learners' experiences, and enhances essential competencies such as problem-solving and clinical reasoning. Ultimately, these strategies can foster learners' readiness to transfer their competencies into real-world clinical practice.

To further establish the value of IVR-based nursing education, outcome evaluations should move beyond learner satisfaction and knowledge acquisition to encompass higher-level outcomes, such as behavioral change, patient outcomes, and healthcare system impacts. Demonstrating value at these higher levels is critical to justifying investment in IVR technologies and ensuring their sustainable adoption in nursing curricula and healthcare systems.

Finally, nursing educators and researchers should pay attention to interaction modes in the design of IVR-based education. Advancing from simple controller-based operations, natural interaction modes—such as speech recognition, gesture-based interaction, and multi-sensory engagement—can deepen immersion and authenticity. By enabling learners to engage with virtual patients and environments in ways that mirror authentic clinical communication, these approaches support the development of both technical and non-technical skills. Ultimately, positioning multimodal and natural interactions as core pedagogical considerations, rather than supplementary features, will be essential for the sustainable advancement of IVR-based nursing education.

4.2. Limitations

There are several limitations to this study. First, this study analyzed interaction modes according to the classification of technological interactions in IVR, and when descriptions of these interactions were limited in the included studies, relevant preliminary research, platforms, and websites were consulted for further analysis. As this study focused solely on undergraduate nursing students, studies involving nurses or other healthcare providers were not included. Furthermore, only studies with quantitative variables were included, indicating that learners' qualitative experiences were not addressed.

5. Conclusion

This scoping review identified the key aspects of IVR-based nursing education, including scenario design, types of virtual humans, pre-briefing and debriefing practices, equipment, outcome variables, and interaction modes. The findings indicate that while IVR holds promise as a pedagogical innovation, current applications remain largely exploratory, with outcome evaluations concentrated on lower levels and interaction modes dominated by controller-based approaches. To advance the field, IVR must evolve beyond procedural training to foster higher-order competencies and integrate more natural, multimodal interactions. Strengthening pedagogical frameworks and expanding outcome evaluations will be essential to establishing IVR as a sustainable and transformative component of nursing education.

Abbreviations

ARDS	Acute respiratory distress syndrome
CINAHL	Cumulative Index to Nursing and Allied Health Literature
COPD	Chronic obstructive pulmonary disease
ER	Emergency room
ERIC	Education Resources Information Center
HMDs	Head-mounted displays
ICU	Intensive care unit
INACSL	International Nursing Association for Clinical Simulation and Learning
IVR	Immersive virtual reality
JBI	Joanna Briggs Institute
NICU	Neonatal intensive care unit
NUI	Natural user interface
NWKM	New World Kirkpatrick Model
PRISMA-ScR	Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews
VR	Virtual reality
VPs	Virtual patients
MeSH	Medical Subject Headings

CRediT authorship contribution statement

Sunghwa Na: Writing – review & editing, Writing – original draft, Visualization, Investigation, Formal analysis, Data curation, Conceptualization. **Jihyung Son:** Writing – review & editing, Investigation, Data curation. **Hyun Joo Lee:** Writing – review & editing, Supervision, Funding acquisition.

Ethical approval

This study is a scoping review and does not involve any primary data collection from human participants. Therefore, ethical approval was not required.

Funding sources

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (No. RS-2022-00166500).

Declaration of competing interest

None.

Acknowledgements

We would like to express our sincere gratitude to Professor Yeonsoo Jang of Yonsei University College of Nursing for providing invaluable feedback on the manuscript through the Research Residency II course. Additionally, we are grateful to Librarian Dami Jung of Yonsei University Medical Library for her assistance in reviewing the search strategies.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.nedt.2025.106877.

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