REVIEWS

Virtual reality simulation enabling high level immersion in undergraduate nursing education: A systematic review

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ABSTRACT

Background and objectives: Virtual reality simulation (VRS) can be used to complement experiential learning, as it enables nursing students to further learn and refine nursing skills outside of the clinical setting. However, gathering evidence for its effectiveness as a teaching method in achieving learning outcomes is still ongoing, and thus there is a lack of systematic synthesis. The objective of this systematic literature review is to analyze VRS scenarios with a high level of immersion and their impact on learning outcomes in nursing education.
Methods: A literature search was performed in the MEDLINE, CINAHL, and ERIC databases in November 2022. As a result, fifteen studies were included and analyzed using deductive content analysis.
Results: The studies reported twelve different scenarios for virtual reality simulations with high levels of immersion, the focus of which was on acute critical care, broader nursing processes, neonatal and pediatric care, single nursing interventions, and observation of patients' symptoms. The associated learning objectives were mainly achieved in the domains of cognition and psychomotor skills.
Conclusions: There are several VRS scenarios that show potential for use in nursing education. The VRS scenarios are effective in improving learning outcomes, particularly those related to knowledge and skills. Overall, the supportive body of evidence gained through this review may help nurse educators in integrating virtual simulations in their curricula. In the future, nursing and adult learning theories should be given greater consideration, and the aspect of affective learning could be included in design and implementation. Moreover, future research could benefit from exploring the long-term effects of learning after using VRS with a high level of immersion to provide valuable evidence for developing VRS teaching methods in nursing.

Key Words: Virtual reality, Virtual reality simulation, Nursing education, Experienced learning

1. INTRODUCTION

Virtual reality simulation (VRS) can be used to complement experiential learning, as it enables nursing students to further learn and refine nursing skills outside of the clinical setting.[1] Competence in nursing skills is essential for a newly graduated nurse and the most important requirement for the safe

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implementation of patient care.[2] In considering best practices in the design and implementation of simulations, up to 50% of clinical experience can be effectively provided using simulations.[3] This could be crucial in exceptional situations like the COVID-19 pandemic. Additionally, it has been predicted that, given the potential associated with rapidly progressing development and digital innovation, VRS will become an integral part of nursing education.[4,5] However, more evidence is needed on the effectiveness of scenarios and the achievement of learning outcomes to support the implementation of VRS.

VRS is a teaching method where the experiential learning of an authentic nursing practice situation is recreated through virtual reality.[6] Due to the variety of definitions for virtual reality (VR) used in the literature, its effectiveness as a teaching method has been difficult to establish.[7–10] The International Nursing Association for Clinical Simulation and Learning (INACSL) Standards Committee defines VR as a digitally created environment that simulates the authentic world and can be experienced by the senses.[11] A more precise definition can be established by assessing and incorporating the level of immersion and presence enabled by the VR.[8] The level of immersion refers to the extent to which the user can perceive and interact with the simulated environment through their own body movements.[12] Immersion refers to the user's psychological reaction as a response to the stimuli provided by VR. The level of presence refers to the feeling of being in a simulated environment and depends on the user's ability to ignore stimuli from the physical environment. The level of immersion in VR is device-dependent[13] and can be divided into low, moderate, and high.[14] A higher level of immersion usually leads to a higher level of presence.[13]

The development and subsequent implementation of VRS for nursing education requires targeted planning to optimize the achievement of expected learning outcomes and the efficient use of resources.[15] The literature provides ample evidence to support the use of VRS with low to moderate levels of immersion.[9,10,16] This approach has demonstrated effectiveness in nursing education when used in conjunction with the acquisition of knowledge[9,10,16] or skills,[1,9] critical thinking, self-confidence, and learner satisfaction.[9] However, although there is also discussion on the potential use of VRS with a high level of immersion in simulation-based nursing education,[17] gathering evidence for its effectiveness as a teaching method in achieving learning outcomes is still ongoing[1] and thus there is a lack of systematic synthesis.

The objective of this literature review is to analyze VRS scenarios with a high level of immersion and their impact on learning outcomes in nursing education. This literature review seeks to answer the following research questions:
(1) What kinds of scenarios have been developed for VRS with a high level of immersion in nursing education?
(2) How have the learning outcomes achieved using VRS with a high level of immersion been evaluated and what are the outcomes?

2. METHODS

2.1 Literature search strategy

The review was a systematic review and followed a predetermined unpublished protocol. A literature search was conducted in the MEDLINE, CINAHL, and ERIC databases from the earliest available date through to 30 November 2022. In addition, a manual search to reference lists of included studies was conducted to identify studies that were not retrieved by the primary search.

The search strategy was constructed for each database according to their instructions. The search terms were decided by the research team and were based on theoretical literature in the field: "virtual reality", "nursing/midwifery student" and "education". Following this, a search sentence was formulated as follows: virtual reality OR virtual environment OR virtual world OR mixed reality OR augmented reality OR artificial environment OR immersive virtual reality AND nursing student OR midwifery student AND education OR training OR learning. The search was limited to full-text and peer-reviewed articles in the English language. No time limit was applied. The search provided a total of 1,317 hits.

The following inclusion criteria were used for the studies: 1) the study was conducted in nursing education, 2) VRS was performed with head-mounted displays (HMD) and hand controllers or haptics, 3) participants were nursing and/or midwifery students, and 4) the study was an empirical study published in English. Studies were excluded if 1) they were conducted in continuing professional education, 2) VRS was performed on a desktop, smartphone application, or with HMD without hand controllers or haptics, or 3) participants were other than nursing and/or midwifery students.

2.2 Study selection process

After removing duplicates (n = 258), the study selection process (see Figure 1) was conducted manually in two phases. Two reviewers, working independently, screened the titles and abstracts (n = 1,059) and the full texts (n = 47). Disagreements between the two reviewers' assessments during any phase were resolved by discussion or, when necessary, by consulting a third review author. A total of fifteen studies were included in the final analysis. The reasons for exclusion at the full-text stage are documented and presented in Figure 1.

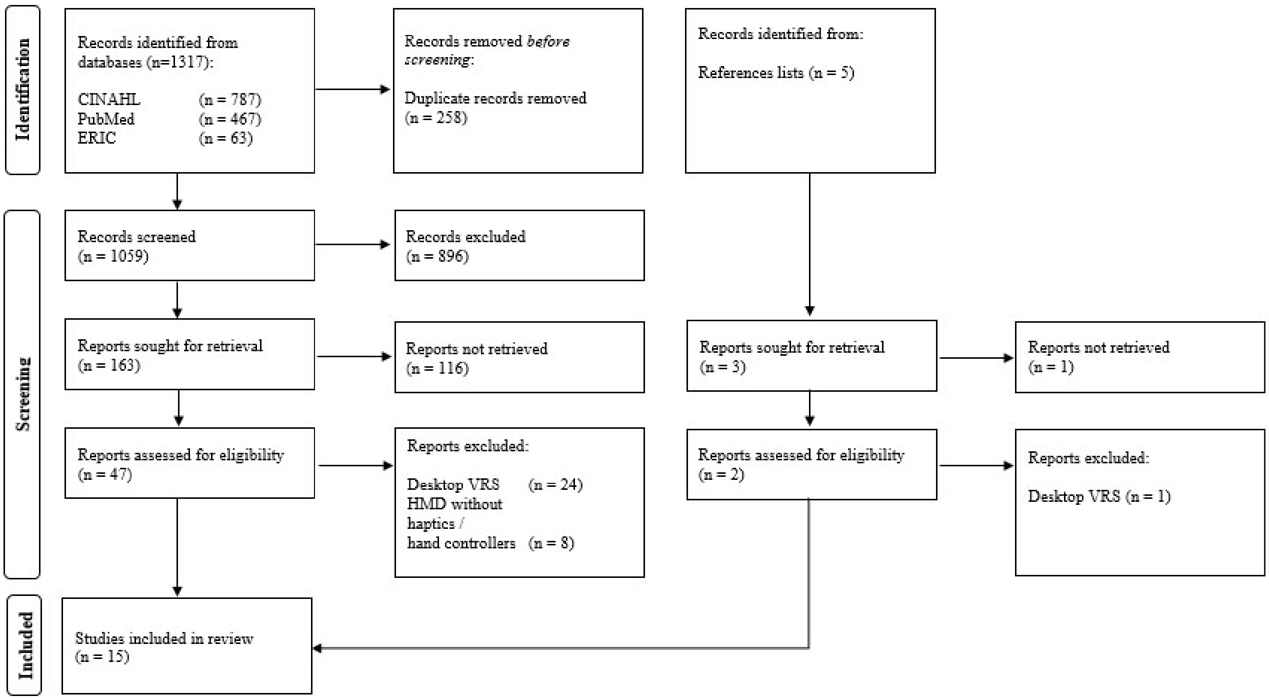

Figure 1. Study selection process in accordance with the PRISMA statement
Adapted from: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/

2.3 Data collection process

Data from the original studies were collected in a tabularized format. One researcher (KP) collected and tabularized the data independently. Following this, the tabularized data sheets were checked and confirmed by members of the research team. The collected data included the following: authors, publication year, country, study design, participants, description of scenarios, data collection, data analysis, learning outcomes, and main results. The original expressions of the publications were used, and no interpretation or imputation of potentially missing information was done.

2.4 Quality appraisal

The quality of the studies was assessed using the Mixed Methods Appraisal Tool (MMAT).[18] The MMAT critical appraisal tool was developed to assess the methodological quality of various study designs and was therefore selected for use in this systematic review. The tool consists of two general questions for each type of study and five items divided specifically into different study designs (qualitative, quantitative randomized controlled trials, quantitative non-randomized, quantitative descriptive, and mixed methods). Each question is given a response from the options "yes", "no", and "can't tell". The quality of the studies was assessed by two researchers who first worked independently and then discussed their evaluations to reach a consensus.

2.5 Data analysis

A deductive content analysis was used based on previous knowledge on simulation in nursing education.[19] A structured analysis matrix was developed for each research question (see Tables 2 and 3) based on Healthcare Simulation Standards of Best PracticeTM simulation design[15] guidance. These standards were used for data analysis, because the design and development of simulations in health care should be based on criteria that provide the best possible conditions to achieve the expected learning outcomes. As the focus of this literature review is on scenario development and the evaluation of learning outcomes, the following criteria were included in the data analysis: needs assessment (criterion 2), learning objectives (criterion 3), theoretical framework (criterion 4), pre-briefing (criterion 8), debriefing (criterion 9), and evaluation methods of learning outcomes (criterion 10).[15] The data were placed in the analysis matrices, and the analysis was performed based on frequencies. The results of the analysis were narratively summarized.

The level of immersion of the VRS in the included studies was assessed by members of the review team (KP, HV, MS). The assessment was guided by the taxonomy of Slater and Wilbur,[20] which was further developed by Miller and Bugnariu[14] (see Table 2). Slater and Wilbur[20] defined the level of immersion as the extent to which the used technology enables the user to perceive and interact with the simulated environment. The taxonomy considers five technological aspects that manipulate the senses of the user and influence the experienced level of immersion: (1) inclusiveness, (2) extensiveness, (3) surrounding, (4) vividness, and (5) matching.[20] Inclusiveness refers to the extent to which awareness of the physical environment caused by the devices used can be excluded. Extensiveness refers to how many sensory modalities are stimulated, such as visual, auditory, and motor. Surrounding refers to the extent to which the field of view is presented for the user and how the physical environment is excluded. Vividness refers to the extent to which fidelity, resolution, and the features of the VR are presented. Matching refers to the extent to which movements of the user's body segments match with the perspective displayed in VR.[14] Depending on the extent to which the used VR technology fulfills these aspects, the level of immersion can be assessed as low, moderate, or high.[14]

The assessment of the level of immersion was included in the data analysis because it brings clarity to the definition of VR in each article and helps to describe and differentiate the scenarios.[8] The impact of VRS on the nursing students' learning (see Table 3) was assessed using Bloom's revised taxonomy of educational objectives.[15]

3. RESULTS

3.1 Characteristics of the included studies

The studies on VR with a high level of immersion in nursing education included in this literature review (n = 15) covered the period from 2018 to 2022 (see Table 1). Half of the included studies were conducted in the USA (n = 6), one of them in collaboration with Korea. Other countries of publication were Brazil (n = 1), Ireland (n = 1), Norway (n = 2), Korea (n = 1), Singapore (n = 1), Taiwan (n = 2), and Turkey (n = 1). Participants in the studies were either exclusively nursing students (n = 12) or they formed a part of the study alongside medical students (n = 2) or newly graduated nurses, midwifery students (n = 1), health workers (n = 1), and faculty members (n = 1). Common to all the included studies was the employment of HMDs with haptics/hand controllers (n = 15). A wide range of different study designs/methodologies was used in the included studies. Experimental design approaches (n = 8) included non-inferior parallel group open randomized control trials (RCTs), experimental pretest-posttest design, quasi-experimental one-group pretest-posttest design, and quasi-experimental design with postintervention assessments. Mixed methods (n = 3), methodological design (n = 2), and single group descriptive design (n = 1) were also reported. One included study did not detail the study design approach undertaken. Data were analyzed purely by statistical methods in almost all studies (n = 13). In addition, content analysis was undertaken in two studies that also used qualitative methods for data collection (see Table 1.)

The methodological quality of all the studies was predominantly assessed as high. The reason for the few criteria that could not be assessed was that reporting contained no or only unclear information. The assessment of the blinding of outcome assessors was particularly challenging in the included RCTs,[21–24] as was the consideration of confounders in the case of quantitative non-randomized trials.[25–29] Despite these few unclear aspects, all fifteen assessed studies were included in the subsequent analysis.

3.2 Scenarios for virtual reality simulation

Twelve different scenarios for VRS were identified (see Table 2). The scenarios focused on acute critical care,[21,22,24,26–28] preoperative nursing processes,[30,31] neonatal infection and pediatric care,[29,30,32,33] and single nursing interventions to include urinary catheterization,[23,25] vacuum blood collection,[34] and observation of patients' symptoms.[35] The storyboard was based on evidence,[13,33] clinical situations,[35] and expert experience,[27–32,35] and it was constructed in collaboration with researchers, content experts,[26–29,31–33,35] educational experts,[26,28] nursing students,[31,34] and information technology specialists.[23,25,29,30,32,34] In some studies, the scenario development process was not reported.[21,22,24]

The VRS lasted between 10 and 45 minutes, with 20 minutes or less in almost half of the studies (n = 9). The level of immersion of the VRS was predominantly rated as high. In five studies, the level of immersion was rated as moderate to high, because motion capture was limited to body segments[23,25,30,34,35] and only two sensory modalities were activated.[35]

Regarding the theoretical basis of VRS, none of the included studies reported that the VRS was based on nursing theory as a theoretical and/or conceptual framework for the scenario. Almost half of the studies (n = 7) reported the use of an adult learning theory, which were the Deliberate practice theory,[23] Skinner's study on operant conditioning behavior,[34] Bauman's layered-learning model,[26] the NLN/Jeffries simulation theory,[27,28] and the Situated learning theory.[25,33]

Table 1. Study characteristics

Author (Year), Country [Ref.]	Purpose	VRS technology	Participants	Study design	Instrument	Data analysis	Results
Berg & Steinsbekk (2020) Norway[21]	*…to investigate if self-practice of the ABCDE approach in VRS gave non-inferior learning outcome compared to using traditional equipment.*	Single player with HMD and hand controllers	Medical and nursing students IG (n = 149) CG (n = 140)	Non-inferior parallel group open RCT	System Usability Scale (SUS)	Statistical analysis	The way of practicing was liked more from students in VRS, and it was seen as a good learning opportunity. Usability of VRS was scored higher than traditional equipment.
Berg & Steinsbekk (2021) Norway[22]	*…to investigate if group self-practice of the ABCDE approach in a multiplayer VRS gave non-inferior learning outcome compared to using traditional equipment.*	Multi player with HMD and hand controllers	Medical and nursing students IG (n = 146) CG (n = 143)	Non-inferior parallel group open RCT	SUS	Statistical analysis	The time to practice in a multiplayer VRS displeased more students. Students felt more confident to conduct an ABCDE examination after practicing with traditional equipment. Usability of VRS and traditional equipment were scored equally.
Butt et al. (2018) USA[23]	*…to explore the usability of and reaction to the first iteration of the VR system designed to practice urinary catheterization.*	Single player with HMD and haptics including sensory gloves	Nursing students IG (n = 10) CG (n = 10)	Mixed method study	SUS User-reaction survey	Statistical analysis	A clear majority rated the VRS as good or excellent, user-friendly, felt confident to use it, and would appreciate regular use. All participants considered VRS being engaging and supporting the correct insertion of a catheter.
Chang (2022) Taiwan[25]	*…to explore the effect of IVR on learning performance and satisfaction.*	Single player with HDM	Nursing students with a previous bachelors degree (n = 43)	Quasi experimental	Learner satisfaction and learning impact questionnaire	Statistical analysis	The majority of students were satisfied with IVR-education. IVR helped them to overcome difficulties in learning catheterization skill and memorizing the procedure.
De Souza-Junior et al. (2020)[34] Brazil	*… to develop and validate the first immersive VRS addressing vacuum blood collection in adult patients.*	Single player with HMD and Leap motion controller	Health workers (n = 15) Nursing students (n = 15)	Methodological design	Assessment form for face and content validation	Statistical analysis	The VIDA-Nursing v1.0 was considered as valid to teach vacuum blood collection in adult patients.
Lee et al. (2020) Korea[35]	*… to evaluate the usefulness of VRS for mental health nursing education.*	Single player with HMD and hand controller	Nursing students (n = 60)	Mixed method study	17-item usability scale statement 7-item open-ended questionnaire	Statistical analysis Qualitative analysis	VRS was found useful, exciting, engaging, and motivating to learn about mental health nursing.
Rossler et al. (2019) USA[24]	*… to examine the effectiveness of the Virtual Electrosurgery Skill Trainer (VEST) on operating room safety skills among prelicensure nursing students.*	Single player with HMD and haptics	Nursing students IG (n = 5) CG (n = 15)	Experimental pretest-posttest design	Perioperative Performance Evaluation Tool for Nursing	Statistical analysis	VEST was considered as a mechanism to consistently and effectively offer education about operating room safety skills.
Ryan et al. (2022) Ireland[32]	*…to explore the effectiveness of Virtual Reality Learning Environment (VRLE) in increasing knowledge retention in midwife education.*	Single player with HMD and hand controllers	Midwifery students (n = 41)	Mixed methods study	Fetal position knowledge assessment questionnaire (MCQ) Virtual Reality Design Scale (VRDS) Student satisfaction and self confidence in learning Scale (SCLS)	Statistical analysis	VRLE learning increased student satisfaction and self confidence in learning. VRLE did not significantly improve students' knowledge level, but improved their anatomical understanding.
Samosorn et al. (2020) USA[26]	*… to examine whether an educational intervention with a pilot contemporary immersive VRS for airway management builds knowledge and is feasible to implement among nursing students and faculty.*	Single player with HMD and hand controllers	Faculty members (n = 10) Nursing students (n = 21)	Quasi-experimental one-group pretest-posttest design	Presence questionnaire VR sickness questionnaire	Statistical analysis	The level of presence of the VRS was rated as high not inducing cybersickness.
Smith et al. (2018) USA[27]	*… to assess two levels of immersive VRS to teach the skill of decontamination."*	Single player with HMD and hand controllers	Nursing students IG (n = 59) CG (n = 58)/desktop CG (n = 55)/written material	Quasi-experimental design with postintervention assessments Focus group interviews	Decontamination checklist	Statistical analysis Qualitative analysis	Students expressed their satisfaction with immersive VRS and found it to be more interactive than desktop VRS.
Siah et al. (2022) Singapore[30]	*…to evaluate efficacy attitude and confidence level of nursing students through VRS*	Single player with HMD and haptics	3rd year nursing students (n = 207)	Single-group descriptive design	Perceptions of nursing–related aspects of patient safety pre–, intra–, peri-, and postoperative settings + questions developed for this study.	Statistical analysis	VRS can be used to apply skills required from scrub nurses in the perioperative environment.
Smith et al. (2020) USA[28]	*… to evaluate two different methods for teaching the skill of decontamination based on three participant outcomes satisfaction, self-confidence and performance.*	Single player with HMD and hand controllers	Nursing students IG (n = 60) CG (n = 60)	Quasi-experimental design with postintervention assessments	NLN Student Satisfaction and Self Confidence in Learning Scale Decontamination checklist	Statistical analysis	There were no statistically significant differences in self-efficacy and satisfaction between the groups.
Taçgın (2020) Turkey[31]	*… to evaluate the perceived effectiveness of designed immersive VR learning environment concerning learning, attitude, and confidence for the different level learners.*	Single player with HMD and haptics	Nursing students 3rd year (n = 14) 1st year (n = 57)		Simulation effectiveness tool	Statistical analysis	The designed immersive VR learning environment was perceived as effective by 3rd year students. Repeated practice had a statistically significant impact on the confidence of students with prior knowledge. Statistically significant positive correlation was found between 1st year students learning, attitude, and confidence
Yu & Mann (2021) Korea/USA[33]	*… to develop an immersive VRS program for teaching basic neonatal infection control to nursing students and newly graduated nurses.*	Single player with HMD and Leap motion controller	Nursing students Newly graduated nurses	Methodological design		Statistical analysis	The three scenarios developed for teaching basic neonatal infection control deal with basic care, nutritional management, skin care and environmental management for transferred newborns.
Wu, Chao & Xiao (2022) Taiwan[29]	*…to examine the impact of VRS on knowledge acquisition compared to a traditional lecture based approach.*	Single player with HMD and hand controllers	Nursing students IG (n = 53) CG (n = 52)	Quasi-experimental with two-group pre-posttest design	Seizure Management Knowledge Test (SMKT) Pediatric Seizure management Virtual Reality Acceptance Questionnaire (PSM-VRAQ) Virtual Reality Sickness Questionnaire (VRSQ)	Statistical analysis	Posttest scores of Knowledge test significantly higher in both groups. Posttest scores of IG were significantly higher.

Note. VRS = virtual reality simulation; VR = virtual reality; IG = intervention group; CG = control group.

Table 2. Scenarios for virtual reality simulation

Author, (Year), [Ref.]	**Scenario**	**Technology**	**Level of immersion***	**Theoretical framework†**		**Needs assessment†**	**Length of VRS**	**Pre-briefing†**	**Debriefing/ feedback†**
				Nursing theory	Adult Learning theory				
Berg & Steinsbekk (2020)[21]	ABCDE approach	Single player with HMD and hand controllers	High	NR	NR	Essential skill Patient safety	20 min	Lecture, video, instruction to VRS	Feedback on performance automatically generated.
Berg & Steinsbekk (2021)[22]	ABCDE approach	Multi player with HMD and hand controllers	High	NR	NR	Essential skill Patient safety	20 min	Lecture, video, instruction to VRS	Feedback on performance automatically generated.
Butt et al. (2018)[23]	Urinary catheterization	Single player with HMD and haptics including sensory gloves	Moderate - high	NR	Deliberate practice theory	Essential skill Patient safety	45 min	Instruction to VRS	NR
Chang (2022)[25]	Urinary catheterization	Single player with HMD and hand controller	Moderate-high	NR	Situated learning theory	Essential skill Patient safety	NR	Instruction to VRS	NR
De Souza-Junior et al. (2020)[34]	Vacuum blood collection	Single player with HMD and Leap motion controller	Moderate - high	NR	Skinner's study on operant conditioning behaviour	Common procedure Patient safety	NR	NR	NR
Lee et al. (2020)[35]	Clinical symptoms of schizophrenia patients	Single player with HMD and hand controller	Moderate - high	NR	NR	Complexity of phenomenon Quality of care	20 min	Instruction to VRS	Feedback on performance automatically generated.
Ryan et al. (2022)[32]	Fetal lie, position and presentation	Single player with HMD and hand controller	High	NR	NR	Essential skill Patient safety	NR	Instruction to VRS	NR
Rossler et al. (2019)[24]	Fire safety knowledge and skills	Single player with HMD and haptics	High	NR	NR	Essential skill Patient safety	NR	Didactic education, discussion, instruction to VRS	NR
Samosorn et al. (2020)[26]	Airway management	Single player with HMD and hand controllers	High	NR	Bauman's layered-learning model	Few existing teaching methods	20 min	Narrated lessons included in VRS	Feedback on performance automatically generated.
Shiah et al. (2022)[30]	Surgical work process for scrub nurses in perioperative care	Single player with HMD and hand controller	Moderate-High	NR	NR	Essential skill Patient safety	15 min	Video, instruction to VRS	Feedback on performance automatically generated.
Smith et al. (2018)[27]	Disaster-specific skill of decontamination	Single player with HMD and hand controllers	High	NR	The NLN/Jeffries simulation theory	Essential skill Patient safety Few existing teaching methods	10 min	Video, instruction to VRS	NR
Smith et al. (2021)[28]	Disaster-specific skill of decontamination	Single player with HMD and hand controllers	High	NR	The NLN/Jeffries simulation theory	Essential skill Patient safety Few existing teaching methods	10 min	Video, instruction to VRS	NR
Taçgın (2020)[31]	Preoperative process	Single player with HMD and haptics	High	NR	NR	Essential skill Patient safety	10-30 min	Seminar, instruction to VRS	Feedback on performance automatically generated.
Wu et al. (2022)[29]	Pediatric seizure management	Single player with HMD and hand controllers	High	NR	NR	Essential skill Patient safety	10-15 min	Instruction to VRS	Feedback on performance automatically generated.
Yu & Mann (2021)[33]	Neonatal infection control	Single player with HMD and Leap motion controller	High	NR	Situated learning theory	Essential skill Patient safety Difficult to offer experiential learning in clinical environment	10-15 min	NR	Feedback on performance automatically generated.

Note. VRS = virtual reality simulation; HMD = head mounted device; NR = not reported.
*based on the criteria developed by Slater and Wilbur (1997) and further developed by Miller and Bugnariu (2016).
†based on INACSL Standards of Best Practice: Simulation^{SM} Simulation Design (2021).

In all of the studies, the evidence-based needs assessment for creating the VRS was based on a review of previous literature. Furthermore, guidelines,[22] recommendations and standards[22,34] as well as organizational[24] and educational needs[33] were used. As a result of the needs assessment, the main reason for creating the scenario was to improve patient safety (n = 10)[21–24,27,28,30,31,33,34] and learn essential and common nursing skills (n = 12).[21–25,27–29,31–34] The limited availability of appropriate teaching methods other than VRS (n = 4)[26–28,30] and the difficulty of offering experiential learning in the clinical environment (n = 1) were also mentioned[33] as justifications for the use of VRS.

Instruction to VRS as a pre-briefing conducted in person or in video format was used in the majority of the scenarios (n = 10), either on its own[23,25,32,35] or in combination with a video[21,22,27,28,30] and/or lecture on the subject matter.[21,22,24,31] Automatic feedback on performance immediately after the VRS (n = 8) was the only debrief mentioned.[21,22,26,31,33,35]

3.3 Evaluation methods and learning outcomes

The discussion in this section is limited to the research results from those studies that include an evaluation of learning outcomes (n = 12) (see Table 3). The achievement of learning outcomes was mostly evaluated using a questionnaire,[25,29–32] knowledge test,[26] or post-simulation practical test on a partial task trainer[23] or a high-fidelity mannequin.[28] A combination of these evaluation methods was used in four studies.[2,21,24,27][None of the studies that compared learning outcomes achieved by practicing the respective skills in VRS against practicing with authentic equipment (n = 5) reported statistically significant differences between the groups' learning outcomes.[21–23,27,28,32] Evaluation methods were commonly developed for the purposes of a single study.[25–27,30,32] Some studies used validated[24,28,31] or adapted[29] instruments to measure the level of knowledge or acquired skills. A criterion-based checklist traditionally used in nursing education at one school was applied to evaluate urinary catheterization skills.[23] In addition, instruments developed for checking the order of eight observations in the ABCDE approach on the practical test[21,22] was used to demonstrate learning outcomes. However, the validity and reliability of these instruments were seldom reported.

All VRS scenarios were shown to have an impact on both cognitive and psychomotor learning (see Table 3). However, the learning outcomes of participants in didactic education differed from those who participated in VRS scenarios in addition to didactic education. In the subsequent practical test, the results achieved by participants who only took part in didactic education were not as good as those achieved by participants whose education included VRS.[24] VRS has been proven to improve knowledge acquisition.[24,26] The effectiveness of learning in VRS increased if the participant had a positive attitude towards VRS and felt confident in practicing nursing skills in a virtual environment.[31]

4. Discussion

A total of twelve different scenarios for VRS with predominantly high levels of immersion developed for nursing education were identified. The scenarios focused mainly on acute critical care but also on broader nursing processes, single nursing interventions, and the observation of patients' symptoms. The learning outcomes were evaluated using knowledge tests, questionnaires and/or practical tests. The learning outcomes achieved were exclusively in the domains of cognitive and psychomotor skills. However, the learning outcomes achieved by VRS did not result in significant differences compared to outcomes achieved by other educational simulation approaches, such as skills lab methods.

The scenarios focused on several areas of nursing care, but acute critical care was the most dominant category. This finding reflects the wide range of possibilities of using VRS in nursing education. A strong focus on acute critical care VRS may be explained by the need to master procedural and psychomotor skills in demanding patient care situations that can be practiced safely in VRS settings. The designed scenarios for VRS with high levels of immersion could be used for formative evaluation of nursing students' knowledge and skills to improve their learning processes towards achieving learning objectives.[36] When used for the summative evaluation of students' competencies with focus on comparing achieved learning outcomes against predetermined criteria, valid and reliable scenario design and evaluation methods are required.[37] Essentially, this represents competency-based education in which the evaluation of learning outcomes ensures that the nursing student has sufficient competencies to enter clinical practice.[38] However, a holistic conception of competence for clinical practice includes the combined application of knowledge, skills, values, and attitudes,[39,40] which is reflected in the three domains of learning, all of which should be considered in a qualitative assessment of the clinical competence of nursing students.[39]

The scenarios developed for VRS in the included studies seem to follow a predetermined and congruent process, starting with setting learning objectives, followed by a pre-briefing and the simulation experience, and concluding with a debriefing and evaluation of learning outcomes.[15] However, the only method of debriefing reported in the studies was automatic feedback on performance generated immediately after the simulation experience.[21,22,26,33,35] Debriefing reduced to automatic feedback only is not sufficient when considering the extreme importance of a facilitator-led and evidence-based debrief for learning outcomes.[41–43] In turn, the constant change and development of simulation design also requires constant adaptation of the debriefing process in order to meet the requirements of this change.

Table 3. Evaluation of learning outcomes

Author, (Year), [Ref.]	Scenario	Domain of learning*	Evaluation methods	Intervention group	Comparison group	Learning outcomes
Berg & Steinsbekk (2020)[21]	ABCDE approach	Cognitive Psychomotor	Questionnaire Practical test	Self-practice with virtual patient and virtual equipment.	Self-practice with authentic equipment.	Self-practice of the ABCDE approach in VRS gave non-inferior learning outcome compared to self-practice with authentic equipment.
Berg & Steinsbekk (2021)[22]	ABCDE approach	Cognitive Psychomotor	Questionnaire Practical test	Group practice with virtual patient and virtual equipment.	Group practice with authentic equipment.	Group practice of the ABCDE approach in VRS gave non-inferior learning outcome compared to group practice with authentic equipment.
Butt et al. (2018)[23]	Urinary catheterization	Cognitive Psychomotor	Practical test	Self-practice of urinary catheterization in VRS.	Self-practice of urinary catheterization on a partial task trainer.	Self-practice of urinary catheterization in VRS gave non-inferior learning outcomes compared to self-practice on a partial task trainer.
Chang (2022)[25]	Urinary catheterization	Cognitive Psychomotor	Questionnaire	Management of in-dwelling urinary catheters in female patients in VRS.	NA	Training helped to overcome the difficulties encountered in learning how to insert Foley catheters inside female patients.
Rossler et al. (2019)[24]	Fire safety knowledge and skills	Cognitive Psychomotor	Knowledge pre- and posttest Practical test	VRS with Virtual Electrosurgery Skill Trainer (VEST).	Didactic education	No statistically significant difference in knowledge acquisition between groups. Greater increase in knowledge from pretest to posttest in VRS group. Self-practice of fire safety knowledge and skills in VRS led to a better performance in the practical test than didactic education only.
Ryan et al. (2022)[32]	Fetal lie, position and presentation	Cognitive Psychomotor	Questionnaire	Fetal lie, position, and presentation in pregnancy.	NA	VRS had no impact on knowledge gain, though high levels of satisfaction and self-confidence indicate a positive response to the VRS.
Samosorn et al. (2020)[26]	Airway management	Cognitive Psychomotor	Knowledge test	Self-practice of airway management in VRS.	NA	The VRS airway laboratory significantly improved knowledge of airway management.
Shiah et al. (2022)[30]	Surgical work process for scrub nurses in perioperative care	Cognitive Psychomotor	Questionnaire	Self-practice of being a scrub nurse in a perioperative environment.	NA	Improved efficacy, attitude, and confidence about nurses' role in perioperative care.
Smith et al. (2018)[27]	Disaster-specific skill of decontamination	Cognitive Psychomotor	Knowledge pre- and posttest Practical test	Self-practice of disaster-specific skill of decontamination in VRS.	1) Self-practice of disaster-specific skill of decontamination on dVRS. 2) Written material.	Cognitive and performance scores were significantly higher immediately after intervention and significantly lower at six months later. dVRS and Written material groups: The time to complete the skill was significantly faster at 6 months than immediately after intervention. No significant differences were found between VRS groups in terms of cognitive scores, performance scores and time to complete the skill.
Smith et al. (2021)[28]	Disaster-specific skill of decontamination	Cognitive Psychomotor	Practical test	Self-practice of disaster-specific skill of decontamination in VRS.	Self-practice of disaster-specific skill of decontamination on a high-fidelity mannequin.	No statistically significant difference in performance, satisfaction, and self-efficacy in learning between groups. Self-practice of disaster-specific skill of decontamination in VRS gave non-inferior learning outcomes compared to self-practice on a high-fidelity mannequin.
Taçgın (2020)[31]	Preoperative process	Cognitive Psychomotor	Questionnaire	Self-practice of preoperative surgical processes in VRS.	NA	A positive attitude towards VRS affected positively learning and confidence of nursing students. Feeling confident affected positively learning and attitude towards VRS. Learning status was affected positively by a positive attitude and a feeling of confidence.
Wu et al. (2022)[29]	Pediatric seizure management	Cognitive Psychomotor	Questionnaire	Seizure management VRS session.	In-person lecture.	The posttest knowledge score in the intervention group was significantly higher than that in the control group.

Note. VRS = virtual reality simulation; dVRS = desktop virtual reality simulation; NR = not reported; NA = not applicable.
*based on Bloom's revised taxonomy of educational objectives.

Evaluation of learning outcomes was done using questionnaires, knowledge tests, and practical tests. What is noteworthy is that many of the studies used evaluation methods that were developed for the purposes of a single study instead of using systematically developed and validated instruments. In the future, the development of an instrument specifically designed to evaluate learning outcomes in the virtual reality environment could promote a systematic and robust approach to evaluation and provide a basis for follow-up studies and, for example, cross-cultural evaluations.

The learning outcomes achieved through VRS with a high level of immersion were in the domains of cognition and psychomotor skills. The result confirms the findings from the previous review[44] but also demonstrates the educational effectiveness of VRS with a high level of immersion in nursing education. This review also identified the importance of the student's motivation and positive attitude towards VRS in achieving the learning outcomes. Learning outcomes need to correspond with teaching methods,[45] and whether the chosen teaching method is the most effective one in achieving the expected learning outcomes should also be considered in order to use resources sensibly. In terms of cognitive and psychomotor skills, there seems to be no difference between VRS with a high level of immersion and other educational approaches, such as skills lab methods. The use of VRS should be considered a complementary method instead of a replacement for the previously used teaching methods.[16,24] The various simulation teaching methods used in nursing education should therefore not be seen as a hierarchical system, in which VRS with a high level of immersion is given the most important status, but rather as a complementary system, in which the individual simulation teaching methods complement each other and are chosen using an evidence-based approach in a resource-efficient way.

It was also evident that none of the studies included in this literature review reported the use of nursing theory as a theoretical and/or conceptual framework for the developed scenario. Instead, approximately half of the included studies reported having used an adult learning theory for this purpose. Both are essential in the design and implementation of simulation-based nursing education, as nursing theories form the body of knowledge unique to the nursing discipline and adult learning theories provide an understanding of the learning and teaching process.[45,46] Carefully chosen theories that are appropriate to the context can support the educator in improving the learning process of nursing students.[44,46]

VRS is a useful alternative to classroom teaching and clinical internships, because it enables contactless and evidence-based learning in nursing practice situations.[1] Based on the research results of this literature review, transitioning extensively from experiential learning to a general use of VRS with a high level of immersion is not necessarily beneficial and should only be seen as a temporary alternative. In order to use the potential of VRS with a high level of immersion more effectively and resource-efficiently in nursing education, it is necessary to discover areas of application in which VRS will prove to be a more effective teaching method than those previously used. This requires continuous research and development of VRS scenarios,[1,16,17] considering standards of best practice for simulation,[3,15] the perspectives of educational designers, nursing teachers, and students,[47] and the needs of nursing education and practice.[15]

Strengths and limitations

The literature search conducted for this review was performed using comprehensive databases with a focus on health sciences and education. No time limit was set in the search to ensure the inclusion of all possible studies conducted over the years. The literature search and selection process as well as the critical appraisal of the included studies were done by two independent researchers. The database search phrases were as similar as possible for each database, with only slightly different terms and rules for each one. For each database search, the date of search, the database search phrase, and the number of articles found were recorded. Although the database search phrases were designed very carefully by the research group and based on previous theoretical knowledge, some relevant search terms may have been left out and thus led to a restricted search result. However, an attempt has been made to ensure that the topic was approached very carefully and that the database search phrases were very comprehensive to minimize this possible limitation.

The analysis was supported by the application of existing criteria, and the result of the analysis was discussed and confirmed in the research group. Achievement of calculated sample sizes was reported in only a few studies,[21,22,28] and there might exist limitations concerning the detection of differences between groups due to inadequate sample sizes. A limitation of this literature review was the non-registration of the review protocol. Reporting was done in accordance with the PRISMA statement.[48]

5. CONCLUSION

This study identified twelve different scenarios for VRS with predominantly high levels of immersion designed for nursing education. The focus of the scenarios was on acute critical care, broader nursing processes, single nursing interventions, and the observation of patients' symptoms. Associated learning objectives were mainly achieved in the domains of cognition and psychomotor skills, and they were evaluated using knowledge tests, questionnaires and/or practical tests. Findings from this systematic review suggest that there was no difference in the learning outcomes achieved via virtual reality simulation with a high level of immersion compared with other educational approaches utilizing simulation. Nursing and adult learning theories should be given greater consideration in the future to develop VRS scenarios for the context of nursing.

Further research would benefit from exploring what kinds of scenarios for VRS with a high level of immersion can be used for affective learning and how affective learning can be evaluated. In addition, a decisive area for further work would be to focus on how long the effect of learning will last after VRS with a high level of immersion and to what extent learning is transferred to clinical practice, which basically should be the ultimate goal of VRS. Furthermore, the impact of VRS with a high level of immersion on motivation theory and lifelong learning processes could be relevant. The descriptions of the designed VRS scenarios in the studies included in this literature review were sometimes very imprecise, a finding that other researchers have already made in connection with studies on VRS.[1,7] Therefore, from the perspective of VRS development, the future description of VR intervention needs to be detailed to include the level of immersion.

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CONFLICTS OF INTEREST DISCLOSURE

The authors declare that there is no conflict of interest.

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