

Review

Methodological approaches and competence areas of nursing students in virtual reality simulation research – A scoping review

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ARTICLE INFO

Keywords:

Virtual reality
Virtual reality simulation
High level of immersion
Nursing education

ABSTRACT

Objectives: To analyze methodological approaches (theoretical frameworks, study designs, methods) and competence areas of nursing students in research on virtual reality simulations (VRS) with a high level of immersion.

Methods: A scoping review was performed. A systematic search of the literature was conducted on MEDLINE, CINAHL and ERIC databases on 30/11/22. In addition, a manual search was utilized. The extracted data relating to the research questions was descriptively analyzed and results were narratively summarized.

Results: In total 23 studies were included in the review. Selected studies employed a wide range of theoretical frameworks and research designs. The studies aimed to develop competences both through complex interventions where team-based skills are required in acute situations, and they described basic nursing interventions where individual skills are required in non-acute nursing care.

Conclusions: A significant amount of the selected studies did not utilize a learning theory or an instructional design framework as a basis for their research. More knowledge was found on training specific skills compared to facilitating the attitudes and values of the participants. Therefore, there is a need for further research on whether nursing students' attitudes and values can be supported through VRS with a high level of immersion.

1. Background

The usage of technology in nursing education has grown exponentially as the technology in the field has advanced (Gause et al., 2022). This effect has been amplified by the Covid-19 pandemic as it has forced educators to develop digital solutions to ensure competence development of nursing students (Palese et al., 2022). Technological advancements have also decreased the cost of virtual reality simulations (VRS) thus improving their accessibility in nursing education (Slater, 2018). Furthermore, VRS is not limited to time or place and created scenarios can be repeated, which makes it a possible substitute for less flexible teaching methods (Shorey and Ng, 2021).

Virtual reality (VR) is a three dimensional digitally generated environment (INACSL Standards Committee, 2016; Cant et al., 2019; Martirosov and Kopecek, 2017) that can be experienced visually, auditorily (INACSL Standards Committee, 2016) and haptically (Shorey and Ng, 2021). Describing the level of immersion has been suggested to clarify heterogeneous definitions of VR in previous literature (Kardong-Edgren et al., 2019). Immersion in VR reflects both the psychological experience of being in an environment and the physical immersion that is created by technological tools engaging the senses (Sherman and Craig, 2018). The level of immersion is connected to the extent to which the VR technology can respond to a learner's action and movement (Slater, 2018) and can be divided into low, moderate, or high (Miller and Bugnariu, 2016). Our

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<https://doi.org/10.1016/j.nedt.2023.106033>

Received 24 July 2023; Received in revised form 26 October 2023; Accepted 5 November 2023

Available online 10 November 2023

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database search found that the first nursing education publications on VRS with a high level of immersion were not until 2018. Therefore, we can conclude that research on the topic is currently in its early stages.

The utilization of theoretical frameworks has been mapped from the perspective of nursing simulations (Lavoie et al., 2018) but it is still unknown whether this knowledge is comparable to VRS research. There are also known methodological limitations in virtual simulation research such as small sample sizes, a lack in reliability reporting and the usage of validated surveys (Coyne et al., 2021). However, from our knowledge no reviews have yet been conducted with a focus on the methodology surrounding VRS in nursing education and previous research does not focus specifically on VRS with a high level of immersion.

Competence development (Weeks et al., 2019) and competence assessment have been studied from the perspective of virtual simulations (Coyne et al., 2021). To our knowledge no previous reviews have been conducted on competences and Virtual reality simulations with a high level of immersion in nursing education. Nursing competence is an important factor in improving the quality of care (Fukada, 2018; Rahmah et al., 2022) although its definitions in the field have been known to be heterogenous (Garside and Nhemachena, 2013; Yanhua and Watson, 2011). This review relies on the definition of competence as the ability to apply knowledge, skills, and attitudes (Watson et al., 2002; Yanhua and Watson, 2011) to varied contexts in nursing practice (Meretoja et al., 2004). Therefore, to extend the scope of research on competences in nursing education to VRS with a high level of immersion and to address aforementioned methodological weaknesses a scoping review was conducted. The objective was to analyze methodological approaches (theoretical frameworks, study designs, methods) and competence areas of nursing students in research on VRS with a high level of immersion. The ultimate objective was to identify research priorities and the extent of research evidence to advance the development of pedagogical methods that support nursing competence acquisition.

2. Methods

A predefined review protocol was planned and agreed within a research team. The protocol was not published or registered. A five-stage scoping review protocol for rigor and transparency by Arksey and O'Malley (2005) was utilized as a methodological framework for the review. The followed five stages of the framework include identifying a research question and relevant studies, study selection, charting data, and collating, summarizing and reporting the results (Arksey and O'Malley, 2005). In addition, the PRISMA-ScR recommendations were followed in reporting the results (Tricco et al., 2018).

2.1. Identifying the research questions

The research questions were identified in collaboration with four researchers (blinded for peer review). This scoping review sought to answer the following research questions:

- (1) What theoretical frameworks, designs and methods have been used to study VRS with high level of immersion in nursing education?
- (2) What competence areas of nursing students were identified in included studies?

2.2. Identifying relevant studies

An organized search of the literature was performed on MEDLINE, CINAHL and ERIC databases on 30/11/22. The PCC (participants/population, concept, context) elements were applied to identify the main concepts of the review questions 'nursing/midwifery student', 'virtual reality' and 'education' (Peters et al., 2020). The search strategy combined MeSH terms and free-text keywords to search phrases. A preliminary search was conducted to MEDLINE database to detect

functionality of the search sentence. The search strategy was adjusted to suit each database. Database searches were limited to full text, peer reviewed articles and English language. By applying these limits, the goal was to identify complete scientific papers on the topic enabling systematic synthesis. The search was not limited in time. It was beyond the scope of this review to contact other authors to identify additional studies. Detailed search strategies for the databases are presented in Appendix Table 1.

Studies were included, if 1) VRS was used for nursing/midwifery education, 2) VRS technology included a Head Mounted Device (HMD) and hand controllers or haptics, 3) participants were nursing/midwifery students or a sample of nursing/midwifery students, and 4) studies were original scientific publications in English. (Table 1).

2.3. Study selection and critical appraisal of the studies

The study selection process was done manually by three reviewers (blinded for peer review). If the results differed, a consensus was sought through discussion and assessment of eligibility.

A critical appraisal of the included studies was conducted using the Mixed Methods Appraisal Tool (MMAT, Hong et al., 2018) to appraise the quality of the studies and to determine the evidence for its relevance, reliability, validity and applicability. Two screening questions ensured that the tool was used in studies intended for this purpose. Following those screening questions, five design-based critical appraisal questions were evaluated using response scale yes/no/unclear (Hong et al., 2018). Three researchers (blinded for peer review) independently assessed the quality of each study. Possible differing results were resolved through discussion.

2.4. Data collection and charting

Data required for answering the research questions were extracted in original expressions by two researchers (blinded for peer review). Items of interest were authors, publication year, country, content of VRS scenario, VRS technology used, participants, study design, data collection, data analysis, and main results. The extracted data was reviewed by members of the research group (blinded for peer review) and checked for accuracy and relevance. Possible missing data was not supplemented through interpretation by the researchers.

2.5. Collating summarizing and reporting results

The extracted and tabulated data relating to the research questions were descriptively analyzed using frequencies and thematic analysis. The frequency analysis focused on study characteristics and thematic analysis on study contents (Braun and Clarke, 2022). Furthermore, to analyze VRS competences the definition of competence as the ability to apply knowledge, skills, and attitudes (e.g., Watson et al., 2002; Yanhua and Watson, 2011) in to varied contexts in nursing practice (Meretoja

Table 1
Inclusion and exclusion criteria for the literature search.

Inclusion criteria	Exclusion criteria
Use of VRS for nursing education	Use of VRS for continuing professional education
VRS using a head-mounted display and hand controllers or haptics	Desktop VRS, smartphone application, head-mounted display without hand controllers or haptics, augmented reality, mixed reality, motion controller
Nursing and midwifery students / sample of nursing and midwifery students	Health professionals and medical students
Original studies published in English	Original studies published in a language other than English

Note. VRS = virtual reality simulation.

et al., 2004) served as a deductive theoretical frame. Finally, results were summarized narratively. Two researchers (blinded for peer review) were involved in the analysis process and consensus was achieved through discussion.

3. Results

3.1. Selection of sources of evidence

Identified records were screened independently by title ($n = 1093$), abstract ($n = 142$), and by full text ($n = 62$). The organized literature search was supplemented by the inclusion of publications found in reference lists of the selected studies. As a result, 23 studies were selected for the final analysis. The study selection process and reasons for exclusion are shown in Fig. 1.

3.2. Characteristics of the studies

As a result of the systematic database search, scientific studies on VRS in nursing education have been published since 1995 with an exponentially increasing trend. Only since 2018 have these publications included studies dealing with VRS with a high level of immersion, a finding confirmed by database searches of other studies (Fealy et al., 2019; Foronda et al., 2020; Woon et al., 2021). Thus, studies included for this scoping review were published between 2018 and 2022 (Table 2).

The selected studies were published in Europe ($n = 7$), USA ($n = 6$), Asia ($n = 5$), Africa ($n = 1$) and South America ($n = 1$). In addition, two further publications were contributed by researchers from Korea and the USA and one publication from Belgium and Canada. In two-thirds ($n = 15$) of the studies participants were exclusively nursing students. The remaining studies also included other participants from the health and nursing education sectors, although nursing students made up an equal

proportion compared to other participants in each of these studies. (Table 2).

The developed scenarios for VRS with a high level of immersion enabled nursing students to acquire competences in different settings. Half of the scenarios ($n = 12$) dealt with complex interventions such as acute nursing in which life-threatening illnesses or an accident of the patient requires immediate action. Most of these scenarios focused on nursing interventions as part of team-based skills. The remaining scenarios ($n = 11$) allowed for the practice of basic nursing interventions required in non-acute nursing care. The practice in these scenarios focused more on individual skills. (Fig. 2). (See Fig. 3.)

3.3. Critical appraisal of studies

Across the included studies the methodological quality was assessed as predominantly high (Appendix Table 2). In qualitative studies, the overall methodological rigor was consistently good. In RCT studies (Berg and Steinsbekk, 2020, 2021; Butt et al., 2018; Rossler et al., 2019) the blinding of outcome assessors was seldom reported. In quantitative non-randomized trials (Samosorn et al., 2020; Smith et al., 2018; Smith et al., 2021) the description of controlling confounders was unclear. Main methodological weaknesses in quantitative descriptive studies were scarcity in description of measurements used and risk of non-response. In mixed methods studies the main critique focused on unclear description of the integration of qualitative and quantitative components. Despite these unclear aspects, all 23 assessed studies were accepted for the subsequent analysis.

3.4. Theoretical frameworks, designs and methods used to study VRS with high level of immersion in nursing education

Learning theories were commonly cited in the selected studies (Butt et al., 2018; Chang and Lai, 2021; Chang, 2022; De Souza-Junior et al.,

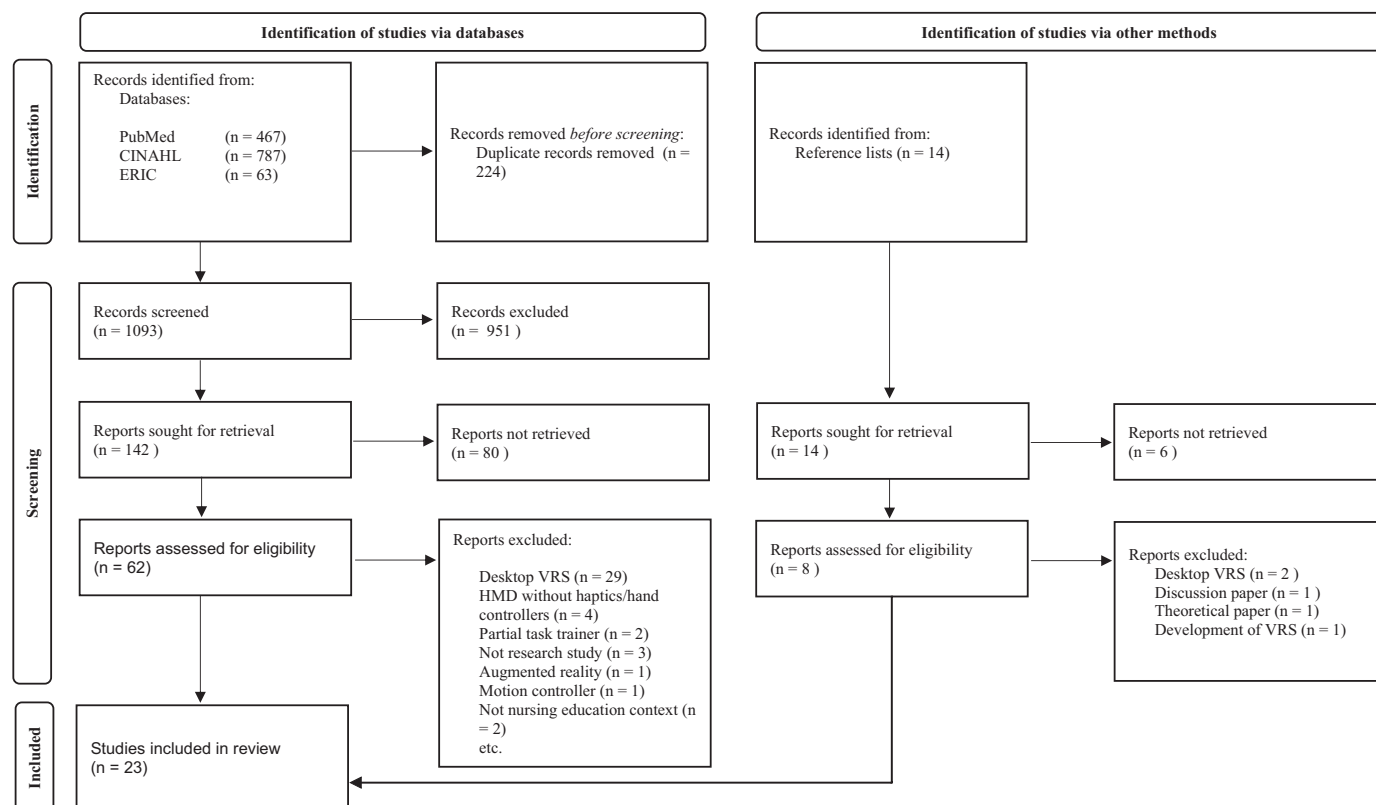


Fig. 1. From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: <https://doi.org/10.1136/bmj.n71>. For more information, visit: <http://www.prisma-statement.org/>

Table 2
Study characteristics.

Author (Year), Country	Purpose	Scenario	VRS Technology	Participants	Research Design	Data Collection		Data Analysis	Results
						Validated Instrument	Other Methods		
Berg and Steinsbekk, 2020Norway	...to investigate if self-practice of the ABCDE approach in VRS gave non-inferior learning outcome compared to using traditional equipment.	ABCDE approach	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)	Baseline questionnaire Post-intervention questionnaire (knowledge and experience) and practical test	Statistical analysis	Non-inferiority in learning outcomes between the groups. Practicing in VRS was liked more and considered as a good learning opportunity. Higher usability scores for VRS.
Berg and Steinsbekk, 2021Norway	...to investigate if group self-practice of the ABCDE approach in a multiplayer VRS gave non-inferior learning outcome compared to using traditional equipment.	ABCDE approach	Multi player with HMD and hand controllers	Medical and nursing students IG (n = 146) CG (n = 143)	Non-inferior parallel group open RCT	SUS	Baseline questionnaire Post-intervention questionnaire (knowledge and experience) and practical test	Statistical analysis	Non-inferiority in learning outcomes between the groups. More students practicing with traditional equipment found the time to practice being sufficient. They also felt more confident to conduct an ABCDE examination. Equal usability scores for both simulation approaches.
Botha et al., 2021South Africa	...to expand on the existing knowledge by providing insight into South African nursing student experiences while being immersed in a VE where they had to manage a virtual patient with a foreign object in the airway.	Foreign object in airway	Single player with HMD and hand controllers	Nursing students Pilot test (n = 6) Final test (n = 28)	NR	SUS After-scenario questionnaire Expectation measure Net Promoter Score Satisfaction rating	Comments during debriefing	Statistical analysis Content analysis	High overall satisfaction and systems usability rating. The completion of the tasks was easy/easier than expected in advance. System was rated as highly recommendable. Cybersickness reduced positive experience for some.
Butt et al., 2018USA	...to explore the usability of and reaction to the first iteration of the VR system designed to practice urinary catheterization.	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	Demographic survey Observation and digital recording of physical and verbal responses during simulation Post-intervention practical test Focus group interviews	Statistical analysis Content analysis	High usability scores for VRS. Practicing urinary catheterization with VRS was rated as fun and engaging. Follow-up demonstration of urinary catheterization skills on a partial task trainer with equal results for both groups.
Chang and Lai, 2021Taiwan	...to understand the experience of nursing students in using virtual reality skill learning process.	Nasogastric tube care	Single player with HMD and motion sensor technology	Nursing students (n = 60)	Qualitative			Content analysis	VRS was seen as a convenient, fast, and stress-free way to learn and practice nursing skills. VRS was considered as resource efficient in terms of time, space, materials, and humans. Sense of reality was felt to be lower compared to traditional simulation methods.
Chang (2022) Taiwan	... to explore the effect of IVR on learning performance and satisfaction.	Urinary catheterization	Single player with HMD	Nursing students with a previous bachelors degree (n = 43)	Quasi experimental	Learner satisfaction and learning impact questionnaire	Records of in Class observation Focus group interviews	Statistical analysis Content analysis	The majority of the students were satisfied with IVR-education. IVR helped students overcome difficulties in learning catheterization skill and memorizing the procedure. Practicing skills through VR was seen as convenient.
De Souza-Junior et al. (2020) Brazil	... to develop and validate the first immersive VRS addressing vacuum blood collection in adult patients.	Vacuum blood collection	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	Video recording of performance	Statistical analysis	The VIDA-Nursing v1.0 was considered as valid to teach vacuum blood collection in adult patients. However, areas for improvement were also identified.
Farra et al., 2018 USA	... to describe participants' experiences and levels of satisfaction with two types of VRS	Decontamination	Single player with HMD and hand controllers	Nursing students (n = 32)	Qualitative as part of a mixed method design		Focus group interviews	Content analysis	Students reported positive learning experiences with both types of VRS. Positive components of VRS were cueing, game-like nature, and active

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Table 2 (continued)

Author (Year), Country	Purpose	Scenario	VRS Technology	Participants	Research Design	Data Collection		Data Analysis	Results
						Validated Instrument	Other Methods		
	<i>with different levels of immersiveness.</i>		Desktop, mouse, and keyboard						participating in the learning process. Occurring technological problems and motion sickness were considered as barriers. VRS with HMD was considered more realistic and immersive.
Havola et al. (2021) Finland	... to evaluate the effects of two kinds of simulation games, a computer-based simulation and a VRS, on self-evaluated clinical reasoning skills by nursing students.	Resuscitation Clinical situations in surgery, internal medicine, emergency, and home healthcare	Single player with HMD and hand controllers Desktop, mouse, and keyboard	Nursing students (n = 40)	One-group pretest-posttest design	Clinical Reasoning Skills scale	Game metrics	Statistical analysis	Self-evaluated clinical reasoning skills improved after playing both kinds of simulation games. Higher playing scores were systematically associated with better self-evaluated clinical reasoning skills. Students spent more time on VRS scenarios with HMD and hand controllers.
Lee et al. (2020) Korea	... to evaluate the usefulness of VRS for mental health nursing education.	Acute schizophrenia care	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	... to examine the effectiveness of the Virtual Electrosurgery Skill Trainer (VEST) on operating room safety skills among preclicensure nursing students.	Fire safety knowledge in operating room	Single player with HMD and haptics	Nursing students IG (n = 5) CG (n = 15)	Experimental pretest-posttest design	Fire Safety Evaluation Pretest-Posttest Perioperative Performance Evaluation Tool for Nursing	Practical test	Statistical analysis	No statistically significant findings in knowledge acquisition for both groups. Transfer of knowledge into practice was performed better after VRS.
Ryan et al. (2022) Ireland	... to explore the effectiveness of Virtual Reality Learning Environment (VRLE) in increasing knowledge retention in midwife education	Anatomical model of fetal position during the third trimester of pregnancy.	Single player with HMD and hand controllers	Midwifery students (n = 41)	Mixed method study	Fetal position knowledge assessment questionnaire (MCQ) Virtual Reality Design Scale (VRDS) Student satisfaction and self-confidence in learning Scale (SCLS)	Baseline questionnaire Open-ended comments	Statistical analysis Thematic analysis	VRLE learning experience was rated highly by students. Increased student satisfaction and self-confidence in learning. VRLE did not affect the students knowledge level in a statistically significant way but there were self-reported experiences of improving anatomical understanding.
Saab et al. (2021) Ireland	... to explore nursing students' perspectives of incorporating virtual reality in nurse education.	Enhance Men's Awareness of Testicular diseases (E-MAT)	Single player with HMD and haptics	Nursing students (n = 26)	Qualitative descriptive study design		Semi-structured interviews Focus group interviews	Thematic analysis	Learning through VR was seen as novel, fun and engaging. Suitable as a complement to traditional teaching methods and learning approaches that provide a safe learning environment. Identified challenges and threats related to financial resources, human interactions, and lack of personal feedback.
Samosorn et al. (2020) USA	... 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.	Airway management	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	Knowledge pretest-posttest Open-ended comments	Statistical analysis Content analysis	Level of presence for VRS was rated as high. Only a few were affected by cybersickness. Statistically significant higher posttest scores for both groups.
Servotte et al. (2020) Belgium/Canada	... to understand the elements that influence the sense of presence among undergraduate healthcare students and postgraduate (PG).	Mass casualty incident	Single player with HMD and hand controllers	Nursing students (n = 17) Medical students (n =	NR	Questionnaire sur la Propension à l'Immersion (ITQ—F) VAS	Open-ended questionnaire	Statistical analysis Thematic analysis	The ability to get immersed was positively correlated to the sense of presence. High sense of presence and low level of cybersickness for both groups.

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Table 2 (continued)

Author (Year), Country	Purpose	Scenario	VRS Technology	Participants	Research Design	Data Collection		Data Analysis	Results
						Validated Instrument	Other Methods		
				25) Postgraduate nursing students (n = 19)		Mental Readiness Form			
						Questionnaire sur l'Etat de Présence (PQ-F)			
						Questionnaire sur les Cybermalaises (SSQ-F)			
Siah et al. (2022) Singapore	... to evaluate efficacy, attitude and confidence level of nursing students through VRS	Perioperative environment	Single player with HMD and haptics	3rd year Nursing students (n = 207)	Single-group descriptive design		Pretest survey (sociodemographic information) Posttest survey developed by authors	Statistical analysis	Majority of students reported positive experience of VRS. VRS can be used to apply skills required from scrub nurses in the perioperative environment.
Smith et al. (2018) USA	... to assess two levels of immersive VRS to teach the skill of decontamination.	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	Decontamination checklist Cognitive pretest- posttest	Demographic questionnaire Practical test Recording of performance time Focus group interviews	Statistical analysis Qualitative analysis	Statistically significant higher posttest and posttraining scores immediately after intervention. Statistically significant lower posttest and posttraining scores at 6 months after intervention within the groups. No statistically significant differences between groups. Students were satisfied with both levels of VRS, but immersive VRS activated them more than desktop VRS.
Smith et al. (2021) USA	... to evaluate two different methods for teaching the skill of decontamination based on three participant outcomes satisfaction, self-confidence, and performance.	Decontamination	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	Demographic questionnaire Practical test Recording of performance time	Statistical analysis	No statistically significant differences in performance, satisfaction and self-efficacy between groups.
Taçgin (2020a) Turkey	... to evaluate the perceived effectiveness of designed immersive VR learning environment (IVRLE) concerning learning, attitude, and confidence for the different level learners.	Pre-operative surgical concepts and procedures	Single player with HMD and haptics	Nursing students 3rd year (n = 14) 1st year (n = 57)	NR	Simulation effectiveness tool	Video recording of performance	Statistical analysis	IVRLE was perceived as an effective learning environment by 3rd year students. Repeated practice with IVRLE by students with prior knowledge had a statistically significant impact on their confidence. 1st year nursing students learning, attitude and confidence correlated positively.
Taçgin (2020b) Turkey	... to evaluate the learning status, behaviours, attitudes, and reactions of the participants after using an immersive VR learning environment.	Pre-operative surgical concepts and procedures	Single player with HMD and haptics	Nursing students 3rd year (n = 14)	Qualitative study		Game metrics Observation of performance Video recording of performance Information exam Semi-structured interviews	Statistical analysis Content analysis	IVRLE was perceived as a useful learning environment to achieve desired learning outcomes. Repetitive sessions increased self- confidence and feeling comfortable. Systematic and task-oriented learning was established with each session. Curiosity about IVRLE increased learning motivation through this teaching method.
Wu et al. (2022) Taiwan	... to examine the impact of VRS on knowledge acquisition compared to a traditional lecture-based approach.	Pediatric seizure management	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		Statistical analysis	Level of presence for VRS was rated as high. Only a few were affected by cybersickness. Posttest scores of Knowledge test significantly higher in both groups.

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Table 2 (continued)

Author (Year), Country	Purpose	Scenario	VRS Technology	Participants	Research Design	Data Collection		Results
						Validated Instrument	Other Methods	Data Analysis
Yu and Mann (2021) Korea/USA	... to develop an immersive VRS program for teaching basic neonatal infection control to nursing students and newly graduated nurses.	Neonatal infection control	Single player with HMD and Leap motion controller	Methodological design	Nonequivalent control group design	Questionnaire (PSM-VRAQ)	Literature search	Posttest scores of IG were significantly higher.
						Virtual Reality Sickness Questionnaire (VRSQ)	Expert panel Video recording of actions	
Yu et al. (2021) Korea/USA	... to examine the effects of a VRS program on Korean nursing students' knowledge, performance self-efficacy and learner satisfaction.	Neonatal infection control	Single player with HMD and Leap motion controller	Nursing students IG (n = 26) CG (n = 25)	Nonequivalent control group design	High-Risk Neonatal Infection Control (HirNIC) Competency Scale Knowledge	Demographic questionnaire	The developed VRS program for teaching basic neonatal infection control included basic care, nutritional management, skin care and environmental management for transferred newborns divided into three scenarios. No statistically significant difference in knowledge between groups. Performance self-efficacy increased statistically significantly within both groups, but with greater increase in IG. Significantly higher learner satisfaction scores in IG.
						HirNIC Performance Scale Self-Efficacy Scale Learner satisfaction questionnaire	Statistical analysis	

Note. VRS = virtual reality simulation; VR = virtual reality; IG = intervention group; CG = control group; NR = not reported.

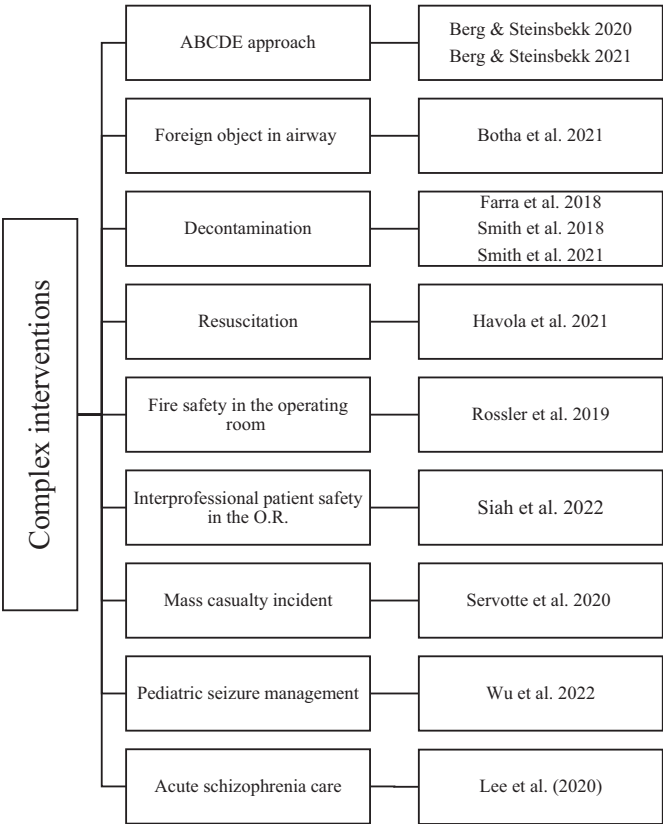


Fig. 2. Complex interventions.

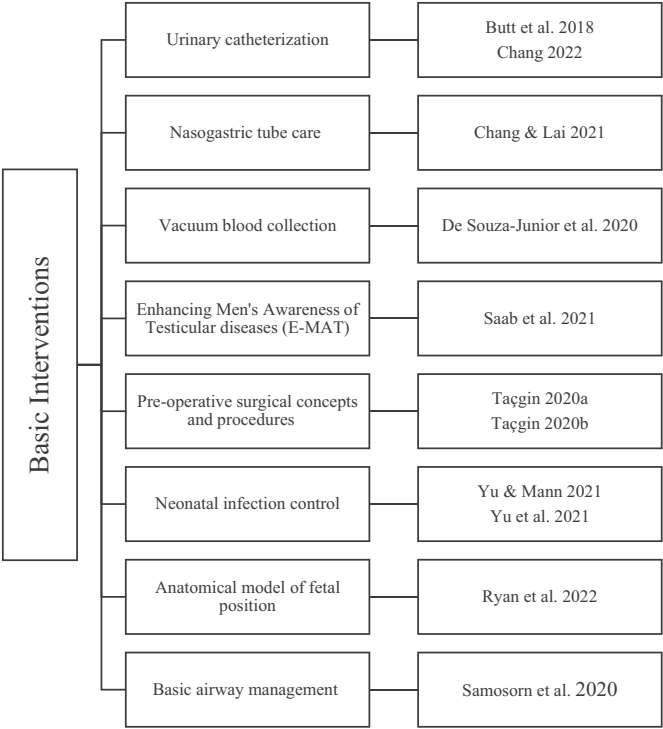


Fig. 3. Basic interventions.

2020; Siah et al., 2022; Taçgin, 2020b; Wu et al., 2022; Yu and Mann, 2021) out of which the most used learning theory was Kolb (1984) experiential learning theory (Chang and Lai, 2021; Siah et al., 2022; Taçgin, 2020b; Wu et al., 2022). Other theories cited were Lave and Wenger (1991) theory of situated learning (Chang, 2022; Yu and Mann, 2021), Skinner (1984) Operant conditioning theory (De Souza-Junior et al., 2020), Ericsson et al. (1993) deliberate practice theory (Butt et al., 2018), Bauman et al. (2014) Layered-learning model (Samosorn et al., 2020) and Zuber-Skennett (1993) theoretical framework of action research (Taçgin, 2020b). Studies also cited the instructional design framework for simulations by National League of Nursing and Jeffries (2016) (Chang and Lai, 2021; Farra et al., 2018; Ryan et al., 2022; Smith et al., 2018, 2021; Yu et al., 2021), which was used to design VRS scenarios (Chang and Lai, 2021; Smith et al., 2018; Yu et al., 2021), to measure constructs in the VRS context (Ryan et al., 2022) and to identify learning outcomes (Smith et al., 2018, 2021). In addition, studies referred to guidelines, standards and protocols (Havola et al., 2021; Rossler et al., 2019; Servotte et al., 2020; Yu and Mann, 2021), the Davis (1989) Technology acceptance model (Wu et al., 2022) or did not cite a theoretical framework (Berg and Steinsbekk, 2020, 2021; Botha et al., 2021; Lee et al., 2020; Saab et al., 2021; Taçgin, 2020a).

The selected studies utilized interventional research designs ($n = 10$), with a quasi-experimental design prevailing ($n = 7$) (Chang, 2022; Havola et al., 2021; Samosorn et al., 2020; Smith et al., 2018, 2021; Wu et al., 2022; Yu et al., 2021), followed by an experimental design ($n = 3$) (Berg and Steinsbekk, 2020, 2021; Rossler et al., 2019). The implemented intervention was VRS with a high level of immersion. The control group practiced with authentic equipment on a mannequin (Berg and Steinsbekk, 2020, 2021; Smith et al., 2021), or received VRS with a lower level of immersion (Havola et al., 2021; Smith et al., 2018). Other interventions for the control group were didactic education (Rossler et al., 2019; Wu et al., 2022), written material (Smith et al., 2018) or participating in clinical practice (Yu et al., 2021). Researchers used the interventional design to examine the effectiveness of VRS as a teaching method for different nursing skills (Chang, 2022; Havola et al., 2021; Rossler et al., 2019; Samosorn et al., 2020; Smith et al., 2018; Smith

et al., 2021; Yu et al., 2021), to investigate non-inferiority of learning outcomes between groups (Berg and Steinsbekk, 2020, 2021), and to examine the feasibility of VRS for implementation in nursing education (Samosorn et al., 2020) (Table 3).

Other research designs used were mixed methods ($n = 4$) (Butt et al., 2018; Farra et al., 2018; Lee et al., 2020; Ryan et al., 2022), and qualitative designs ($n = 3$) (Chang and Lai, 2021; Saab et al., 2021; Taçgin, 2020b) with a focus on user reaction (Butt et al., 2018), experiences (Chang and Lai, 2021; Farra et al., 2018), and perspectives (Saab et al., 2021). A single group descriptive design ($n = 1$) (Siah et al., 2022) was also utilized. Methodological designs were chosen for development ($n = 2$) (Yu and Mann, 2021; De Souza-Junior et al., 2020) and validation of a VRS with a high level of immersion (De Souza-Junior et al., 2020). The research design was not reported in some studies (Botha et al., 2021; Servotte et al., 2020; Taçgin, 2020a; Taçgin, 2020b). (Table 3.)

A validated instrument as data collection method was common as some selected studies utilized multiple validated instruments ($n = 10$) and others ($n = 5$) used one. The most used instrument was the *System Usability Scale* (SUS) ($n = 4$) (Berg and Steinsbekk, 2020, 2021; Botha et al., 2021; Butt et al., 2018). Additional data collection methods in interventional and mixed method studies were questionnaires/knowledge tests either before and/or after the intervention ($n = 10$), post-interventional practical tests ($n = 6$), and/or game metrics ($n = 2$) with subsequent statistical analysis. Qualitative data collection and analysis methods have been applied in qualitative as well as in mixed methods and methodological studies. Methods used were individual and focus group interviews ($n = 6$), observation ($n = 3$) and video recording ($n = 4$) with subsequent content analysis. In addition, studies with not reported research designs collected data through comments during debriefing sessions ($n = 1$) and an open-ended questionnaire ($n = 1$). (Table 3.)

3.5. Description of competences in included articles

The VRS competences were categorized based on the definition of competence (e.g., Watson et al., 2002; Yanhua and Watson, 2011) as knowledge, skills and attitudes.

In two studies competences were examined from the perspective of the three competence areas (Smith et al., 2021; Lee et al., 2020). However, in one article competences were evaluated through knowledge and skill acquisition without examining participants' attitudes (Rossler et al., 2019). The selected studies described varied nursing competences including cognitive competence, such as, knowing preoperative tasks and surgical equipment (Taçgin, 2020b), infection control competence in the neonatal context (Yu et al., 2021), competence in patient safety (Rossler et al., 2019), communication competence and competence for schizophrenia care (Lee et al., 2020), the competence of preparing and reacting to disasters (Smith et al., 2018) and specific competences such as catheterization competence (Chang, 2022). Some studies also recognized the need for further research in the areas of clinical competences such as seizure management (Wu et al., 2022) and infection control (Yu and Mann, 2021).

3.6. Knowledge areas and knowledge acquisition supported through VRS

Knowledge areas that studies aimed to support through VRS included clinical knowledge (Ryan et al., 2022; Havola et al., 2021), theoretical knowledge and procedural knowledge (Taçgin, 2020b). The studies also mentioned more specific descriptions and measurements such as of knowledge about clinical observation (Berg and Steinsbekk, 2021), decontamination (Smith et al., 2018) fire safety (Rossler et al., 2019), position of fetus in the womb (Ryan et al., 2022), neonatal infection control (Yu et al., 2021), airway management (Samosorn et al., 2020), specific concepts and tasks in the perioperative environment (Taçgin, 2020b), seizure management (Wu et al., 2022), and nursing in the mental health context (Lee et al., 2020).

Table 3
Research design and methods.

Characteristic	<i>n</i>
Research Design	
Interventional	
Quasi-experimental	7
Experimental	3
Mixed methods	4
Qualitative	3
Methodological	2
Not reported	3
Data Collection – Validated Instrument	
Single	5
Multiple	10
Data Collection – Other Methods	
Questionnaire	10
Interviews	6
Video recording	4
Game metrics	2
Practical test	6
Written test	2
Comments	3
Observation	3
Literature search	1
Expert panel	1
Data analysis	
Statistical analysis	18
Qualitative analysis	11

Note. The variation in sample size is due to missing values. *n* = number of participants.

The results on knowledge acquisition were varied and at times conflicting. Some articles reported no significant differences in knowledge acquisition between VRS group and intervention group with traditional methods (Smith et al., 2018; Yu et al., 2021). There were also articles that reported VRS significantly increasing knowledge level both in VRS and control group (Samosorn et al., 2020; Wu et al., 2022) and in one article knowledge test scores were significantly higher in students who participated in VRS education if compared to control group with traditional teaching methods (Wu et al., 2022). In contrast there were articles that reported VR having no effect on knowledge acquisition (Rossler et al., 2019; Ryan et al., 2022). However, students' experiences reflected increased understanding of the topic (Ryan et al., 2022) and applying knowledge in practice was considered better in the VRS group (Rossler et al., 2019).

3.7. Skill areas and skill acquisition supported through VRS

Multiple articles aimed to develop clinical skills through VRS (Berg and Steinsbekk, 2021; Yu and Mann, 2021). More specific clinical skills described in the articles included skills in clinical reasoning (Havola et al., 2021; Yu and Mann, 2021), assessment (Taçgin, 2020a), observation (Berg and Steinsbekk, 2020), decision making (Lee et al., 2020; Saab et al., 2021; Taçgin, 2020a) and problem solving (Saab et al., 2021; Yu and Mann, 2021). The articles also described aiming to support procedural skills (Butt et al., 2018; Wu et al., 2022), psychomotor skills (Saab et al., 2021; Taçgin, 2020a; Taçgin, 2020b; Yu and Mann, 2021) practical skills (Saab et al., 2021; Taçgin, 2020a) and basic caregiving skills (Chang and Lai, 2021; Chang, 2022). Additionally, the articles aimed to develop cognitive skills such as critical thinking skills (Siah et al., 2022; Taçgin, 2020a) and communication skills (Wu et al., 2022).

A majority of the articles ($n = 12$) focused on complex interventions such as skills necessary in acute care situations where immediate action is required. More specific skills and competences in this area include the ABCDE observation approach (Berg and Steinsbekk, 2020, 2021), resuscitation (Havola et al., 2021), decontamination (Farra et al., 2018; Smith et al., 2018, 2021), fire safety (Rossler et al., 2019), foreign object management in the airway (Botha et al., 2021), mass casualty incident management (Servotte et al., 2020), pediatric seizure management (Wu et al., 2022) interprofessional patient safety in the operation room (Siah et al., 2022) and acute schizophrenia care (Lee et al., 2020).

The remaining articles ($n = 11$) focused on practicing basic nursing interventions and individual skills and essential for everyday clinical practice. The interventions included in this category focused on the skills of urinary catheterization (Butt et al., 2018; Chang, 2022), nasogastric tube care (Chang and Lai, 2021), vacuum blood collection (De Souza-Junior et al., 2020), neonatal infection control (Yu and Mann, 2021; Yu et al., 2021), visualization of fetal position during pregnancy (Ryan et al., 2022), ability to increase awareness of testicular diseases (Saab et al., 2021), pre-operative surgical concepts and procedures (Taçgin, 2020a; Taçgin, 2020b), and basic airway management (Samosorn et al., 2020).

In 6 studies VR was reported as an effective teaching method in achieving nursing skills (Havola et al., 2021; Rossler et al., 2019; Samosorn et al., 2020; Smith et al., 2018, 2021; Yu et al., 2021). In two studies the learning outcomes of immersive VRS were non-inferior if compared to practicing skills with traditional equipment (Berg and Steinsbekk, 2020; Berg and Steinsbekk, 2021). Similarly post practical skill demonstration had equal results whether students learned through VRS or traditional equipment (Butt et al., 2018; Smith et al., 2021). Additionally, students reported that VRS enhanced previously learned skills (Saab et al., 2021) and that it could be used in their application (Siah et al., 2022). VRS was also found to be a valid tool to teach specific nursing procedures such as blood collection (De Souza-Junior et al., 2020).

3.8. Participants attitudes regarding VRS

Participants were reported having a positive attitude towards learning through VR (Chang, 2022; Siah et al., 2022) and they considered VR to be an acceptable (Samosorn et al., 2020; Wu et al., 2022), effective (Siah et al., 2022) and efficient as a learning method (Taçgin, 2020a). Having a positive attitude on VR increased students' confidence and helped them learn (Taçgin, 2020a). VRS was also found to increase participant's level of confidence (Taçgin, 2020a; Taçgin, 2020b; Ryan et al., 2022; Saab et al., 2021; Siah et al., 2022) and self-efficacy in learned skills (Siah et al., 2022; Yu et al., 2021). These effects increased if learners had previous experience with VR (Siah et al., 2022).

Additionally, students showed appreciation for the technology (Ryan et al., 2022) and believed that VR could be used to support empathy and equity between students through providing them with equal learning opportunities (Saab et al., 2021). Students also considered VR to be a useful method in learning skills (Chang, 2022; Havola et al., 2021; Wu et al., 2022), and overcoming difficulties in learning and memorizing procedures (Chang, 2022). Students' curiosity in interventions was initially placed on the VRS technology but with repeated practice it did extend towards the topic being learned (Taçgin, 2020b).

Students did however question whether VRS could allow them to train in patient centered care (De Souza-Junior et al., 2020) and teaching staff had doubts about VRS being integrated into nursing curriculum (Samosorn et al., 2020). Students also experienced anxiety and stress when they lacked technological skills to use VR although these feelings decreased with practicing the scenario repeatedly (Taçgin, 2020b).

4. Discussion

Our scoping review revealed that research on VRS with a high level of immersion is in early stages, which is consistent with previous reviews (Fealy et al., 2019; Foronda et al., 2020; Woon et al., 2021). This review has identified theoretical frameworks, methodological approaches and competence areas in nursing education research on VRS with high level of immersion.

The methodological quality of most of the selected studies was assessed as high. There were however methodological weaknesses such as insufficient reporting of study design (Botha et al., 2021; Servotte et al., 2020; Taçgin, 2020a; Taçgin, 2020b), lack of assessment of blinding in RCTs (Berg and Steinsbekk, 2020, 2021; Butt et al., 2018; Rossler et al., 2019) and confounders in non-randomized trials (Samosorn et al., 2020; Smith et al., 2018; Smith et al., 2021). The methodological weaknesses in the randomization and blinding in RCTs is consistent with previous literature on virtual simulations (Coyne et al., 2021).

Lavoie et al. (2018) reported that most research on nursing education simulation does not cite a learning theory and instead utilizes an instructional framework guiding the design of the study. This was consistent with our review since only a third of the articles cited a learning theory (Butt et al., 2018; Chang and Lai, 2021; Chang, 2022; De Souza-Junior et al., 2020; Siah et al., 2022; Taçgin, 2020; Wu et al., 2022; Yu and Mann, 2021) and a fourth were based on an instructional design framework (Chang and Lai, 2021; Farra et al., 2018; Ryan et al., 2022; Smith et al., 2018, 2021; Yu et al., 2021). In addition, multiple studies cited no theoretical framework (Berg and Steinsbekk, 2020, 2021; Botha et al., 2021; Lee et al., 2020; Saab et al., 2021; Taçgin, 2020a). Therefore, we can conclude that theoretical shortcomings found in simulation research are consistent in the field of VRS. The selected articles had a wide range of research designs, the most common being interventional, mixed methods and qualitative. (Table 2.)

A limited number of articles analyzed how their methods supported nursing competences or described theoretical frameworks relating to competence development. Some articles did, however, recognize the need for further research on nursing competences and VRS (Wu et al.,

2022; Yu and Mann, 2021). Our review recognized knowledge, skills, and attitudes that studies aimed to develop. We found a larger body of work on training nursing skills and procedures while less had been published on facilitating the values and attitudes of nursing students. Participants had positive attitudes towards VRS (Chang, 2022; Siah et al., 2022) and their confidence levels and self-efficacy increased more if learners had previous VR experience (Siah et al., 2022). In addition, repeated practice with VRS also extended students' interest from the VRS technology towards the topic being learned (Taçgın, 2020b). This supports VRS as an effective learning activity for acquisition of nursing competences, once the learners become familiar with the technology. It also highlights the need to provide sufficient time and instructions for the students to get acquainted with the technology and give them equal opportunities to learn with modern methods.

4.1. Strengths and limitations

A scoping review was chosen to examine emerging evidence of the topic as research on VRS with a high level of immersion is in early stages (Fealy et al., 2019; Foronda et al., 2020; Woon et al., 2021) and there is a need to map the extent of research on the topic. The scoping review process does however have limitations. The systematic literature search was conducted in three scientific databases covering research from health sciences, nursing and education. However, the search was limited to studies that had full text version available. This limitation might have introduced a selection bias as some relevant studies without full text version might have been missed. However, to overcome this limitation the reference lists of included studies were also inspected to detect possibly relevant studies. The heterogeneous nature of the selected studies could limit the generalizability of the results. To produce critically appraised and synthesized results a quality appraisal using MMAT tool (Hong et al., 2018) was conducted. Some studies had methodological weaknesses but were still included in the review since they included relevant information to identified research questions. Research on VRS seem to be rapidly evolving thus highlighting the need to synthesize the most recent developments in this field.

5. Conclusion

This scoping review identified theoretical frameworks, methodological approaches and competence areas in nursing education research on VRS with high level of immersion. Our review found that current research employs a wide range of theoretical frameworks and research designs with limitations comparable to previous simulation research. A significant amount of the selected studies did not utilize a learning theory or an instructional design framework as a basis for their research. The studies aimed to develop competences both through complex interventions where team-based skills are required in acute situations, and they described basic nursing interventions where individual skills are required in non-acute nursing care. Learning results were promising in the competence areas of knowledge and skills. However, more knowledge was found on training specific skills compared to facilitating the attitudes and values of the participants. Therefore, there is a need for further research on whether nursing students' attitudes and values can be supported through VRS.

CRedit authorship contribution statement

Criteria	Author Initials
Conceptualization	MS, KP, HV, ND, SS, ILB
Methodology, data collection, analysis	MS, KP, IK, HV, YB
Preparing the manuscript	KP, IK
Drafting the manuscript	MS, HV, ND, LG, CTW, ILB, YF, SS

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.nedt.2023.106033>.

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