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Effectiveness of virtual clinical learning in nursing education: a systematic review

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Abstract

Background With the development of technology in education, simulations, virtual and online technologies are being incorporated into nursing education, especially for clinical education. This was especially necessary when an event occurred that did not necessarily allow for face-to-face contact, such as Covid-19, disasters like typhoons and others. However, limited resources for clinical education of nurses can contribute to the challenges of incorporating and appropriately utilizing virtual clinical learning technologies. Nursing education has been driven by the use of virtual learning technologies such as virtual reality, augmented reality, immersive virtual reality simulation, mixed reality, among others, which are delivered using tablets, phones or computers to create a lived experience for an intended learning outcome. This review aims to examine their effectiveness in terms of core professional competencies, problem solving, nursing process and communication skills.

Methods This systematic review was conducted in accordance with the guidelines of the Preferred Reporting Items for systematic reviews and Meta-Analysis. Experimental peer-reviewed articles (randomized controlled trials, and quasi-experimental studies with one to two or more groups (pre-/post-test) using e-simulation technology for nursing education and assessment were included. PubMed, Embase, PsycINFO and Web of Science were searched. The search duration was from inception to 30th April 2024.

Results Virtual simulation technologies could be used for the practical teaching of nursing students. These technologies have been shown to significantly improve problem-solving skills (effect size 0.2 to 0.9), communication skills (effect size 0.4–0.7), and core professional competencies (effect size 0.3 to 0.9) with a small to large effect size.

Conclusion The results indicate that virtual simulation technologies have important benefits for students' learning when integrated into clinical nursing education and practice. Educators should consider the use of virtual learning technologies when revising nursing curricula. It is important that nursing education policy makers integrate the use of virtual simulation into nurse education, and adapting this pedagogical approach could help improve student readiness for effective healthcare delivery.

Keywords Virtual reality, Simulation, Online, Technology, Nursing education

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Introduction

It has been known for many decades that pandemics affect people's lives and their social and economic behavior. Various influences have fostered changes in the mode of delivery of educational content, to utilizing distance and online content [1, 2]. It is interesting to note that various other technologies such as books, pens, paper and overhead projectors were used in nursing education for centuries. Using computer-based tools it has become possible to make learning fully online by using virtual learning resources for teaching and assessment. The move away from face-to-face learning has had an asymmetric impact on different sectors, but professions that require human contact, such as medicine and nursing, have been the most affected [3]. Although nursing and medical education have experienced an abrupt transition without much time for preparation, the growing literature suggests that integrated virtual learning, including clinical simulations, may be the new norm [4].

Although there is no universally accepted definition of simulation-based education (SBE), Hawker and colleagues consider it to be the use of a tool that can support experiential learning by replicating or creating a set of conditions that resemble a real-life situation [5]. It could create an environment that allows students to learn, make mistakes and self-correct without jeopardizing patients' lives [5]. SBEs can enable individuals to analyze and respond to realistic situations with the aim of improving or developing their skills, knowledge, attitudes or behavior [5]. This approach might promoted the physical, social and cognitive skills of trainee nurses and other healthcare professionals [5]. A number of tools have been developed and integrated into the nursing curriculum to prepare students for the demands of nursing practice through virtual clinical learning.

Virtual clinical learning, as we understand it, is a process in which students interact with computer-based scenarios. Virtual simulation can be defined as "the use of partial immersion in a digital learning environment" — such as tablets, computers, or phones, — to create a lived experience for an intended learning outcome [6].

Virtual clinical simulation could be an alternative approach to deliver meaningful clinical learning experiences that are closer to traditional clinical learning by utilizing virtual learning technologies such as virtual simulators and others to achieve the established curriculum objectives. This could include the use of learning modalities such as screen-based learning, where students learn via the screen, or virtual reality, where they can learn completely virtually or also use the real world (augmented reality). Using these technologies was reported to have impacted nurse education by enhancing students understanding of theoretical knowledge, practical skills, skills retention, alongside satisfaction levels [7].

Although most of the literature on the use of virtual-learning for teaching and assessment in nursing education has emerged in the last two decades, simulation technologies have been used in nursing education for several decades [8]. Medical simulations involve realistic virtual environments and mimic disease situations, including changes in physiological parameters [9]. Evidence has shown that virtual simulations (VS) in combination with face-to-face teaching have enormous potential to improve the learning experience [3]. Performing virtual simulations using simulators could provide an objective assessment of technical nursing skills by maintaining realism, pathology and active bleeding conditions in a controlled laboratory environment [10]. Such practical patient simulations might offer the opportunity to practice skills without risk to live patients [11]. However, in the form of high-end virtual training (high-fidelity simulators), VS can even induce anxiety in learners as the experience is comparable to real patients [12, 13]. It is therefore expected that a registered nurse should be able to demonstrate these skills to an acceptable level of competence for clinical practice [14]. In addition, these technologies may provide a method for nurses to engage in self-directed lifelong learning [15]. Therefore, virtual e-learning could be a preferred method in the future.

The effectiveness of various high-end virtual technologies in improving learners' clinical skills has been demonstrated in the literature. A meta-analysis has shown that augmented reality has proven to be the most effective method for improving students' spatial skills compared to other virtual technologies [16]. In addition, teaching with VR technologies reportedly improves test scores with moderate effect sizes (SMD 0.53) compared to other approaches [17]. It has also been reported that flipped learning based on virtual reality has a positive effect on the complex medical skills of doctors [18]. However, due to the paucity of experimental data, it is difficult to reach a consensus on the effectiveness and safety of virtual-learning in nursing education aimed at QSEN [19].

A number of reviews have explored the use of virtual technologies to examine the state of the art in computer-based virtual nursing education [20, 21]; pedagogical characteristics and student competencies [22, 23]; and concept analysis of virtual simulations and their impact on improving clinical reasoning [24], to identifying best practices [25] and on the acquisition of specific skills, attitudes and knowledge [26, 27]. However, none of the aforementioned studies specifically examined the effectiveness of virtual simulation technologies on communication, problem solving, professional core competencies and the nursing process.

Virtual simulation technologies in nursing are the use of technologies that enable nursing students to perform nursing assessments, implement nursing interventions based on real clinical situations and use the results as a basis for clinical decisions [28]. Simulation technologies in communication are a process of using technology and visualization tools to help students communicate using a model [29]. Using these technologies, students can solve problems and develop core professional skills [30, 31].

The Core Competencies for Nursing Education provide a structured approach to preparing students for nursing roles that takes into account the demands of both practical nursing experience and nursing education. There is a need to explore how the virtual learning medium impacts on students' application of the nursing process, potentially enhancing their core professional competencies. Furthermore, the available reviews did not quantitatively estimate the magnitude of effect to know the extent of the impact of the interventions. Hence, the need for this study.

The review

Objectives

This study examines the effectiveness of virtual simulation technologies on the primary outcomes of communication and problem solving and the secondary outcomes of core professional competencies and the nursing process.

Methods

Design

This study was a systematic review conducted according to the PRISMA guidelines (Preferred Reporting Items for Systematic Review and Meta-analysis) [32].

Study eligibility criteria

Inclusion criteria

Study type: the study included original articles from experimental research such as the randomized controlled trials, and non-randomized controlled trials (e.g., quasi-experimental studies with two or more groups (pre-/post-test) published in the English from inception to 2024.The population included nursing students enrolled at University/College. Interventions included e-materials and virtual patients, blended e-learning, use of technology and platforms, and training and preparation in a virtual disease model.

Exclusion criteria

Individual case studies, case reports, review articles, conference proceedings, qualitative studies, postgraduate theses, or e-based studies with non-nursing participants were excluded.

Sources of information

Three electronic databases were searched (PubMed, Embase, PsycINFO and Web of Science). The search duration was from inception to 30th April 2024.

Search strategy

Key terms used for the data search included: nurs*, simulation OR virtual reality OR computer simulation OR virtual patient OR VISM* OR high-fidelity simulation OR clinical reasoning OR clinical competence OR problem-based learning AND problem solving, and combinations thereof using the AND/OR Boolean operators. The data were exported to the reference management software Endnote for de-duplication.

Selection process

A database search was carried out and all articles were exported to the Endnote reference manager to remove any duplicates and then conduct screenings for eligibility. The screening of the title/abstract according to the eligibility criteria (exclusive and inclusive list) was done by two independent reviewers (**DS & AFA**). A third reviewer (**FA**)was consulted to clarify any discrepancies in the review and quality assessment.

Data collection process

The authors developed a spreadsheet for data extraction. The following information was extracted for the included studies: Author(s) name, year of publication, study design, sample size, participant characteristics (e.g., gender and age), and virtual interventions including dose (i.e., frequency, duration, and course), its modes of delivery, and outcomes (results and their respective outcome measures). These items were extracted by the second author (**DS**), and the first (**AFA**). The third reviewer (**FA**) was invited to resolve any disagreement between the first and the second author.

Risk of bias in individual studies

This review included both RCTs and non-randomized studies. Therefore, the PEDro scale is used to assess the methodological quality of RCTs, as the instrument has been shown to be valid and reliable [33]. It can provide the reader with information about the internal validity of the study, the quality of its statistical reporting and its external validity [33]. To obtain the total score of the PEDro scale, all items were summed, except for the eligibility criteria; however, items 2–9 could be used to obtain the scores of the subscales for internal validity. Similarly, the sum of items 10 and 11 could give the score for the Statistical Reporting subscale. The overall PEDro score could reflect the methodological quality of the RCTs, and a score of 0–3, 4–5, 6–8 and 9–10 could be translated as poor, fair, good and excellent quality, respectively [34, 35].

Summary measures and synthesis of the results

The Cochrane Handbook for Systematic Reviews was used as a guide for data handling [36]. Outcome data were extracted (mean and standard deviation) at baseline, post-intervention, and possibly follow-up from all eligible studies. Effect sizes were considered trivial (<0.1), small (0.1–0.3), moderate (0.3–0.5), and large (>0.5) respectively [37]. A random effects model was used to examine the differences between the effects of the intervention and control groups. This is possibly because different instruments could be used to measure the results of individual studies. The pooled effects were examined at T1 between the two study arms using Review Manager 5.3. Heterogeneity was reported using the I^2. The I^2 was used to quantifies different degrees of heterogeneity as low (25%), moderate (50%), and high (75%) [38, 39]. In accordance with the Cochrane Handbook for Systematic Reviews of Intervention, an I^2 of 50% might be indicative of serious level of heterogeneity [40]. The sources of heterogeneity are investigated in the meta-analysis if there are high values (i.e., sensitivity analysis) [41]. In the absence of RCTs required for meta-analysis, we calculated the mean changes in effects for the intervention and control groups and the effect between groups using the post data for the intervention and control groups, respectively.

Results

Study selection

As shown in Fig. 1, a total of 11,190 studies were identified from the Web of Science (*n* = 651), PubMed (*n* = 8,591), Embase (*n* = 1,725), PsycINFO (*n* = 219), and hand search (*n* = 4). A total of 1,418 duplicate references were identified and removed using the Endnote Reference Manager. After deduplication, a total of 9,772 references were subjected to title screening. Records after title and abstract screenings were 121. Records included after full-text screening, a total of sixteen were found eligible for inclusion. However, four studies were removed for not having appropriate data. Thus, the review included twelve primary studies.

Demographic characteristics

As shown in Table 1, a total of 12 studies were included. The majority (*n* = 9) were quasi-experimental studies published between 2012 and 2024. Across all included studies, participants were 928 nursing students of whom 430 were female. The overall mean age range was 19.0-22.9 years.

The intervention types and dose

The documented intervention activities included simulation-based education with scenarios and a virtual reality-based situated learning system (see Table 1). The studies documented educational components for learning such as student self-discussion, instructor debriefing,

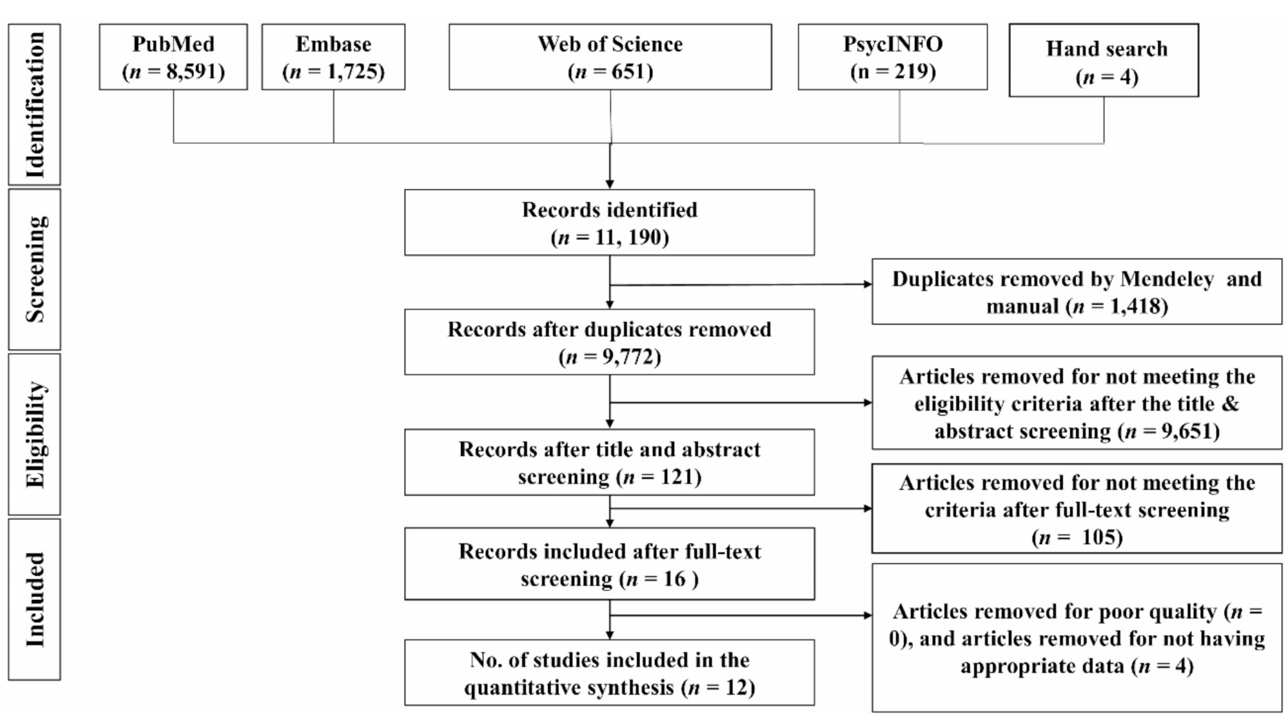

Fig. 1 PRISMA flow chart

Table 1 Study characteristics

No	Author	Year	Design	Population				Intervention	Comparison	Outcomes		Dose
				Age# Years or Range or Mean/SD	Gender Female (%) or M(SD)	Sample size	Samples conditions			Variables	Instruments	
1	Kim [42]	2012	Quasi-experimental	Exp = 22.4(1.3) Cont = 22.4(1.3)	NA	70	Nursing students	Simulation-based education	Conventional pre-clinical practice orientation	Communication skills Clinical competence Nursing process Direct nursing intervention Psychosocial nursing Education for patients Basic nursing performance Physical examination patient and monitoring	Communication skill tool Clinical competence tool	D: NR C: 5 weeks F: 3 sessions
2	Lee [43]	2016	Quasi-experimental	10(20.4)	NA	49	Nursing students	Clinical reasoning	Usual care	Nursing core competencies Academic self-efficacy Problem solving	Nursing core competencies measurement tool, Academic self-efficacy tool Problem solving skills tool	D: 120-minutes C: 16-weeks F: weekly
3	Choi [44]	2018	Quasi-experimental	21.7(2.2)	55(94.8)	58	Nursing students	Practicum with AEMR	Conventional Practicum	Critical thinking Satisfaction	Critical thinking Disposition Scale Self-developed scale	D: NR C: NR F: NR
4	Kang & Yu [45]	2018	Quasi-experimental	Cont = 21.9(2.6) Exp: 21.6(1.0)	Cont: 60(95.2) Exp: 53(88.3)	123	Nursing students	SSD and ID	Received only ID	Problem solving Perceptions of instructors' efficacy in conducting debriefing Debriefing satisfaction	Problem Solving Process inventory Team effectiveness tool DASH 10-cm visual analogue scale	D: 4-hours C: 5-sessions F: unclear
5	Bate [46]	2019	Quasi-experimental	NA	115(87.5%)	132	Nursing students	*Active role*	*Observers' role*	Anxiety Satisfaction Self-confidence in learning Clinical ability Problem solving Confidence in clinical practice Collaboration	STAI SCLS SLEI	D: NR C: NR F: NR

Table 1 (continued)

No	Author	Year	Design	Population				Intervention	Comparison	Outcomes		Dose
				Age# Years or Range or Mean/SD	**Gender Female (%) or M(SD)**	**Sam-ple size**	**Samples conditions**			**Variables**	**Instruments**	
6	Kim [47]	2019	Quasi-experimental	Exp 22.9 (2.8) Cont 22.7(1.9)	32(94.1)	74	Nursing students	Simulation	Self-directed learning	College life Satisfaction Number of simulations Experience Self-confidence Assessment Diagnosis Implementation Evaluation Clinical judgment Noticing Interpreting Responding Reflecting Clinical decision making Search for alternatives or options Canvassing of objectives and values Evaluation and reevaluation of consequences Search for information and Unbiased assimilation of new information	Self-confidence for problem-solving CDMNS	D: 70-minutes C: NR F: NR
7	Oh [48]	2021	RCT	TLT = 20.6(0.70) Cont = (20.8(0.6)	NA	56	Nursing students	TLT + Debriefing	TLT only	Knowledge Problem solving Critical thinking disposition Reflection	Knowledge scale questionnaire Problem solving process tool Critical thinking disposition scale Lasater Clinical Judgment Rubric	D: 50-minutes C: three meetings F: NR
8	Seo & Eom [49]	2021	Quasi-experimental	NA	34(75.6%)	45	Nursing students	Simulation nursing education	Clinical traditional practicum	Clinical reasoning Problem-solving process Self-efficacy	OPT model for clinical reasoning Problem-solving process scale Neuroscience Nursing Self-Efficacy Scale	D: 60-hours C: 10-days F: 2-weeks

Table 1 (continued)

No	Author	Year	Design	Population				Intervention	Comparison	Outcomes		Dose
				Age# Years or Range or Mean/SD	Gender Female (%) or M(SD)	Sample size	Samples conditions			Variables	Instruments	
9	Chang [31]	2022	Quasi-experimental	Average age was 21	Unspecified	42	Nursing students	MVR-SLS	Traditional instruction	OSCE competency, problem solving, engagement and learning satisfaction.	LSS, PSQ, OSCE competency examination,	D: unclear C: 3 weeks F: NR
10	Cengiz [50]	2023	RCT	Experimental19.6(1.19); Control 19.4(1.08)	81(72%)	112	Nursing students	Scenario-based simulation	Usual care	Problem solving Self-efficacy	Problem solving inventory Self-efficacy scale	D: 90-minutes C: NR F: 2-days
11	Chang [51]	2024	Quasi-experimental	Unspecified	Unspecified	44	Nursing students	Scenario game-based learning	Adopted video-based learning	Learning performance Communication Collaboration Critical thinking Complex problem solving Creative thinking Computational thinking	Communication, collaboration, complex problem solving, and creative thinking questionnaire, critical thinking tendency scale & computational thinking scale	D: 100 min C: 5 weeks F: weekly
12	Lin [30]	2024	Quasi-experimental	Average 19 years	NA	123	Nursing students	Computational thinking concept based PBL activity	Conventional PBL activity	Learning achievement Problem solving skills Confidence	Self-developed scale Problem solving skills questionnaire Confidence questionnaire	D: NR C: 4-months F: NR

NA = Not Available; STAI = State-Trait Anxiety Inventory for Adults; SCLS = Student Satisfaction and Self-Confidence in Learning Scale; SLEI = Simulation Learning Effectiveness Inventory; RCT = Randomized Controlled Trial; SD = Standard Deviation; SG = Simulation by Gaming; D = Duration; C = Course; F = Frequency; LSS = Learning Satisfaction Scale; AEMR = Academic Electronic Medical Record; DASH = Debriefing Assessment for Simulation in Healthcare; SSD = Student Self Debriefing; TBL = Team Based Learning; PBL = Problem Based Learning; MILD System = Mobile interactive learning and diagnosis; ID = Instructor debriefing; MVR-SLS = Maternity virtual reality-based situated learning systems an academic electronic medical record practicum, and a computation-based problem-based learning activity.

The activities for the control groups in this study included conventional preclinical practice orientation, usual activities, conventional practicum, instructor debriefing, observer role, self-directed learning, Transformative Learning Theory, traditional clinical practicum or instruction, adopted video-based learning, and conventional problem-based learning activity. The duration of the available simulation interventions was a minimum of 50 min and a maximum of 3,600 min with a course of 2-days to 16 weeks with a weekly frequency and or 3–5 sessions for the entire program.

Quality ratings (Risk of Bias)

As shown in Table 2, the quality of included studies ranged from poor ($n=4$, 33.3%) to moderate ($n=8$, 66.7%). However, only two studies randomly allocated their subjects to their respective groups. None of the studies concealed their subject's allocation or blinded the participants, therapist and outcome assessors, respectively. The rate of dropout was minimal as only three studies reportedly had more than 15% rates. No study was omitted as each provided relevant evidence.

Effects of virtual simulation on problem solving

As shown in Table 3, five studies investigated the effects of virtual simulation on problem solving. The effects of simulation on problem solving between groups had a mean change ranging from 0.7 to 16.1 with an effect size ranging from – 0.2 to 0.9corresponding to a small to large improvement [43, 52–55]. In addition, there was a moderate effect for confidence in problem solving (0.4) and approach/avoidance style (0.5) [50].

Effects of virtual simulation on communication

As shown in Table 3, five studies investigated the effects of virtual simulation on communication. The simulation led to an improvement in communication skills with small to large changes with an effect size of 0.4–0.7 [42, 43, 51]. There was also evidence of a small improvement (0.2) in communication with patients or clear communication about the patient's condition (0.1) [46], and a large improvement (0.9) in communication with nurses and other healthcare professionals [44].

Effects of virtual simulation on professional core competencies

As shown in Table 3, the effects of virtual simulation on core professional competencies were examined in four studies. There was evidence of improvement in clinical competencies with an effect size of 0.9 [42]; core nursing competencies 0.3; specialized nursing competencies 0.5; general nursing competencies 0.3; and objective

Table 2 Quality ratings: risk of Bias within studies quality appraisal using PEDro scale

	Author	Year	Eligibility	Randomized allocation	Concealed allocation	Similarity at baseline	blinding of participant	Blinding of therapist	Blinding of assessor	Dropout	Intention to treat	Group comparison	PMVD	Total Score (10)	Internal validity (8)	Sub scale (2)	Interpretation
1	Kim [42]	2012	Yes	No	No	Yes	No	No	No	Yes	Yes	Yes	Yes	5	3	2	Moderate
2	Lee [43]	2016	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	4	2	2	Poor
3	Choi [44]	2018	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	4	2	2	Moderate
4	Kang & Yu [45]	2018	No	No	No	No	No	No	No	No	Yes	Yes	Yes	3	1	2	Poor
5	Bate [46]	2019	No	No	No	Yes	No	No	No	No	No	Yes	Yes	3	1	2	Poor
6	Kim [47]	2019	No	No	No	No	No	No	No	Yes	No	Yes	Yes	3	1	2	Poor
7	Oh [48]	2021	No	No	No	Yes	No	No	No	Yes	No	Yes	Yes	4	2	2	Moderate
8	Seo & Eom [49]	2021	Yes	No	No	Yes	No	No	No	Yes	No	Yes	Yes	4	2	2	Moderate
9	Chang [31]	2022	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	4	2	2	Moderate
10	Cengiz [50]	2023	No	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	5	3	2	Moderate
11	Chang [51]	2024	No	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	5	3	2	Moderate
12	Lin [30]	2024	No	No	No	Yes	No	No	No	No	Yes	Yes	Yes	4	2	2	Moderate

PMVD = Point measures and variability data. Note: Each item was scored either Yes = 1 or No = 0. Items 2–11 are summed for a PEDro total score. The sum of items 2–9 yields the internal validity subscale score, while the sum of items 10 and 11 yields the statistical reporting subscale score. The PEDro total score was rated 0–3 = poor, 4–5 Moderate, 6–8 good, and 9–10 = excellent structured clinical examination (OSCE) competencies 0.7 [31, 43]. The magnitude of the effect could be translated as small-large.

Effects of virtual simulation on nursing process

One study investigated the effects of virtual simulation on the nursing process. There was evidence of a moderate (0.5) effect size for the overall nursing process [42, 47] (Table 3).

Assessment

Three studies investigated the effects of virtual clinical simulation on the assessment phase of the nursing process. There was evidence of a small effect size of 0.1 for assessment and a moderate effect size of 0.4 for physical examination and patient monitoring [47]. Physical examination and documentation reportedly had a small effect of 0.2 [44]; similarly, a moderate effect was found for interviewing patients (0.6), a small effect for observing patients (0.2) and measuring patient data (0.2) [46] (Table 3).

Nursing diagnoses

Three studies investigated the effects of virtual clinical simulation on the nursing diagnosis phase of the nursing process. To be specific, understanding the patient's problems was reported to have a moderate effect of 0.4 [44]. There may be a small effect of 0.2 for the development of nursing diagnoses [46, 47]. However, the diagnosis of patients according to priority and the early recognition of signs and symptoms of deteriorating health status of patients had no effect [44, 46] (Table 3).

Planning

Two studies investigated the effects of virtual clinical simulation on the planning phase of the nursing process. Evidence-based care planning, health education planning and implementation, and shared decision making each had a moderate effect size (0.4) [56, 57]. In contrast, a small effect size was reported for intervention planning and rapid decision on patient care (0.1) and for prioritization of patient care needs (0.2), respectively [46] (Table 3).

Nursing intervention

Two studies investigated the effects of virtual clinical simulation on the nursing intervention phase of the nursing process. The direct nursing intervention had a moderate effect size of 0.5, while the patient education had a large effect size of 0.8 [47]. In addition, the implementation of the planned care intervention achieved a small effect of 0.2 [44, 47]; with a large effect size for nursing intervention and documentation of 0.6 [47] (Table 3).

Evaluation

A study investigated the effects of virtual clinical simulation on the evaluation phase of the nursing process. The evaluation of the outcome of nursing interventions was reported to have a small magnitude of effect with an effect size of 0.2 [44] (Table 3).

Discussion

As far as we are aware, this is the first study to comprehensively investigate the effectiveness of virtual simulation technologies in promoting student nurses' communication skills, problem solving, professional core competencies and the nursing process. Utilizing simulation technologies in teaching and practicum might help students understand topics taught and problems by promoting the understanding of concepts/problems. Specifically, problem solving, professional core competencies, communication skills, and nursing interventions showed small to large improvements.

There was evidence of a small magnitude of effect for the overall nursing process. In particular, the physical examination and documentation, the development of a nursing diagnosis, the planning of an intervention and the implementation of planned nursing measures showed an improvement of small effect size. In the same fashion, prompt decision making about the necessity for patient care as well as the need for patient care itself and the assessment of the nursing interventions performed had a small effect size. On the other hand, physical examination and monitoring of patients, understanding patients' problems, interviewing patients and measuring their data, planning and delivering health education, direct nursing intervention, and shared decision making and evidence-based intervention planning by nurses had a moderate effect size. Above all, the documentation of nursing measures appears to have a large effect size.

Consistent with our findings where we achieved small to large magnitude of effects for the different competencies in nursing, previously published meta-analytic evidence has shown that virtual simulation might promote skills of nursing students and caring with a large magnitude of effect SMD 0.93, 95% CI 0.69, 1.17 and SMD 1.40, 95% CI 0.23, 2.58, respectively [58]. Research has shown that by using simulation technologies, students can practice, make mistakes and then learn from them after receiving feedback from their teachers; this could also help students to repeat the exercises at will [58], To buttress this fact, research has shown that there is no variation between the traditional clinical hours compared to half of the high fidelity hours, there appears to be no statistically significant differences between them in terms of skill performances between 6 and 24 months [56]. On the contrary, in terms of skills performance, there was a variation in terms of effects as high fidelity simulation

Table 3 Between group effects

No.	Author	Year	Group	Variables	Effect size-between group				
					T0M(SD)	T1M(SD)	MΔ (ES)	T2M(SD)	MΔ (ES)
1	Kim [42]	2012	Exp (*n* = 35)	Communication skills	3.7(0.6)	4.3(0.5)	0.3(0.5)*	NA	NA
			Cont (*n* = 35)		3.9(0.6)	4.0(0.6)			
			Exp (*n* = 35)	Clinical competence	3.5(0.5)	4.2(0.4)	0.4(0.9)*	NA	NA
			Cont (*n* = 35)		3.7(0.5)	3.8(0.5)			
			Exp (*n* = 35)	Nursing process	3.3(0.5)	4.0(0.6)	0.3(0.5)	NA	NA
			Cont (*n* = 35)		3.4(0.6)	3.7(0.5)			
			Exp (*n* = 35)	Direct nursing intervention	3.4(0.6)	3.9(0.7)	0.3(0.5)	NA	NA
			Cont (*n* = 35)		3.4(0.6)	3.6(0.6)			
			Exp (*n* = 35)	Education for patients	3.6(0.7)	4.3(0.5)	0.4(0.8)*	NA	NA
			Cont (*n* = 35)		3.9(0.6)	3.9(0.5)			
			Exp (*n* = 35)	Physical examination patient and monitoring	3.3(0.6)	4.0(0.8)	0.3(0.4)*	NA	NA
			Cont (*n* = 35)		3.5(0.6)	3.7(0.7)			
2	Lee [43]	2016	Exp (*n* = 23)	Nursing core competencies (total)	197.0(24.6)	256.5(32.3)	9.2(0.3)*	NA	NA
			Cont (*n* = 26)		229.0(41.4)	247.3(23.2)			
			Exp (*n* = 23)	Special nursing competency	21.3(3.6)	31.2(4.7)	2.5(0.5)*	NA	NA
			Cont (*n* = 26)		26.3(6.4)	28.7(5.1)			
			Exp (*n* = 23)	Understanding humans and Communication	64.3(9.2)	79.6(10.1)	3.1(0.4)*	NA	NA
			Cont (*n* = 26)		70.0(14.6)	76.5(7.4)			
			Exp (*n* = 23)	General nursing competency	34.7(4.7)	46.4(6.4)	0.9(0.3)	NA	NA
			Exp (*n* = 23)	Problem solving	157.7(16.2)	165.2(15.2)	4.8(-0.2)	NA	NA
3	Choi [44]	2018	Exp (*n* = 28)	Communication (Patients)		3.3 (0.4)	0.1(0.2)	NA	NA
			Cont (*n* = 30)			3.2 (0.5)			
			Exp (*n* = 28)	Physical assessment and documentation		2.8 (0.5)	0.1(0.2)	NA	NA
			Cont (*n* = 30)			2.7 (0.6)			
			Exp (*n* = 28)	Implementation of planned nursing intervention		2.9 (0.6)	0.1(0.2)	NA	NA
			Cont (*n* = 30)			2.8(0.5)			
			Exp (*n* = 28)	Understanding of patients' nursing problem		3.4 (0.5)	0.2(0.4)	NA	NA
			Cont (*n* = 30)			3.2 (0.4)			
			Exp (*n* = 28)	Outcome evaluation of nursing intervention		2.9 (0.7)	0.1(0.2)	NA	NA
			Cont (*n* = 30)			2.8(0.5)			
			Exp (*n* = 28)	Planning of evidence-based nursing intervention		3.3 (0.4)	0.2(0.4)	NA	NA
			Cont (*n* = 30)			3.1 (0.7)			
			Exp (*n* = 28)	Setting of long and short nursing goal		3.1 (0.5)	0.0(0.0)	NA	NA
			Cont (*n* = 30)			3.1 (0.4)			
			Exp (*n* = 28)	Planning and implementation of health education		3.1 (0.6)	0.0(0.0)	NA	NA
			Cont (*n* = 30)			3.1 (0.6)			
			Exp (*n* = 28)	Communication (Nurses & other healthcare providers)		2.8 (0.4)	0.4(0.9)	NA	NA
			Cont (*n* = 30)			2.5 (0.7)			
			Exp (*n* = 28)	Nursing diagnosis according to priority		3.3 (0.4)	0.0(0.0)	NA	NA
			Cont (*n* = 30)			3.3 (0.5)			
			Exp (*n* = 28)	Nursing intervention and documentation		3.2 (0.5)	0.3(0.6)	NA	NA
			Cont (*n* = 30)			2.9(0.5)			
4	Kang & Yu [45]	2018	Exp (*n* = 60)	Problem solving process		113.7(12.3)	9.9(0.8)*	NA	NA
			Cont (*n* = 63)			103.8(13.1)			
5	Bate [46]	2019	Exp (*n* = 73)	By interviewing patient		4.0(1.0)	0.4(0.6)*	NA	NA
			Cont (*n* = 73)			3.6(1.2)			
			Exp (*n* = 73)	By observing patient		4.2(0.8)	0.2(0.2)	NA	NA
			Cont (*n* = 73)			4.0(1.0)			
			Exp (*n* = 73)	Measuring patient data		4.2(0.8)	0(0.2)	NA	NA
			Cont (*n* = 73)			4.2(0.9)			

Table 3 (continued)

					Effect size-between group				
No.	Author	Year	Group	Variables	T0M(SD)	T1M(SD)	MΔ (ES)	T2M(SD)	MΔ (ES)
			Exp (*n* = 73)	Understanding signs and symptoms for problem identification		4.3(0.8)	0(0)	NA	NA
			Cont (*n* = 73)			4.3(0.8)			
			Exp (*n* = 73)	Developing a nursing diagnosis		4.2(0.8)	0.2(0.2)	NA	NA
			Cont (*n* = 73)			4.0(0.9)			
			Exp (*n* = 73)	Recognizing signs and symptoms early in the event of deterioration in patient's health condition.		4.1(0.8)	0.0(0)	NA	NA
			Cont (*n* = 73)			4.1(0.9)			
			Exp (*n* = 73)	Independent decision making		4.1(0.8)	0.4(0.4)*	NA	NA
			Cont (*n* = 73)			3.7(0.8)			
			Exp (*n* = 73)	Collaborative decision making		3.5(1.2)	0.5(0.4)	NA	NA
			Cont (*n* = 73)			3.0(1.1)			
			Exp (*n* = 73)	Prompt decision regarding patient's care		3.9(0.9)	0.1(0.1)	NA	NA
			Cont (*n* = 73)			3.8(0.9)			
			Exp (*n* = 73)	Prioritize the needs for patient's care		3.7(1.0)	0.2(-0.2)	NA	NA
			Cont (*n* = 73)			3.9(1.1)			
			Exp (*n* = 73)	Setting goals		3.4(1.0)	0(0)	NA	NA
			Cont (*n* = 73)			3.4(1.2)			
			Exp (*n* = 73)	Planning intervention		3.5(1.1)	0.1(-0.1)	NA	NA
			Cont (*n* = 73)			3.6(1.1)			
			Exp (*n* = 73)	Implementing nursing actions		4.1(0.9)	0(0)	NA	NA
			Cont (*n* = 73)			4.1(0.7)			
			Exp (*n* = 73)	Communicating patient's current conditions clearly		4.4(0.8)	0.1(0.1)	NA	NA
			Cont (*n* = 73)			4.3(0.9)			
6	Kim [47]	2019	Exp (*n* = 34)	Assessment		14.9(1.7)	-0.2(-0.1)	NA	NA
			Cont (*n* = 40)			15.1(1.8)			
			Exp (*n* = 34)	Diagnosis		7.6(0 0.8)	0.2(0.2)	NA	NA
			Cont (*n* = 40)			7.4(0 0.9)			
			Exp (*n* = 34)	Implementation		9.8(1.3)	-0.3(-0.2)	NA	NA
			Cont (*n* = 40)			10.1(1.4)			
			Exp (*n* = 34)	Evaluation		3.4(0 0.5)	0.0(0.0)	NA	NA
			Cont (*n* = 40)			3.4(0 0.6)			
7	Oh [48]	2021	Exp (*n* = 26)	Problem solving process	97.6(16.9)	123.0(19.7)	11.6(0.7)*	NA	NA
			Cont (*n* = 30)		105.2(14.0)	111.4(13.2)			
			Cont (*n* = 30)			5.9(0.5)		6.7(1.2)	
8	Seo & Eom [49]	2021	Exp (*n* = 25)	Problem-solving process		74.3(17.3)	10.6(-0.6)	NA	NA
			Cont (*n* = 20)			84.9(17.9)			
9	Chang [31]	2023	Exp (*n* = 21)	OSCE competency		8.6(0.9)	0.6(0.7)*	NA	NA
			Cont (*n* = 21)			8.0(0.8)			
			Exp (*n* = 21)	Problem-solving		4.4(0.6)	1.1(2.2)*	NA	NA
			Cont (*n* = 21)			3.3(0.4)			
10	Cengiz [50]	2023	Exp (*n* = 57)	Problem solving (Confidence in problem solving)	31.5(9.8)	28.2(9.8)	-3.8(0.4)*	NA	NA
			Cont (*n* = 55)		30.7(8.7)	32.0(9.4)			
			Exp (*n* = 57)	Problem solving (Approach-avoidance style)	45.8(14.2)	40.0(11.6)	-5.5(0.5)*	NA	NA
			Cont (*n* = 55)		43.8(12.4)	45.5(11.0)			
			Exp (*n* = 57)	Problem solving (personal control)	17.2(3.2)	16.1(3.2)	-0.4(-0.1)	NA	NA
			Cont (*n* = 55)		17.0(3.2)	16.5(3.9)			
			Exp (*n* = 57)	Problem solving inventory Total	94.5(24.1)	84.3(20.0)	-9.8(-0.5)*	NA	NA
			Cont (*n* = 55)		91.5(19.9)	94.1(18.7)			
11	Chang & Yang [51]	2024	Exp (*n* = 21)	Communication	4.6(0.5)	0.5(0.7)*	NA	NA	NA

Table 3 (continued)

No.	Author	Year	Group	Variables	Effect size-between group				
					T0M(SD)	T1M(SD)	MΔ (ES)	T2M(SD)	MΔ (ES)
			Cont ($n=23$)		4.1(0.8)				
			Exp ($n=21$)	Complex problem solving	4.7(0.5)	0.2(0.3)*	NA	NA	NA
			Cont ($n=23$)		4.1(0.8)				
12	Lin [30]	2024	Exp ($n=63$)	Problem solving skills	4.0(1.0)	4.5(0.4)	0.7(0.9)*	NA	NA
			Cont ($n=60$)		3.8(1.1)	3.8(1.1)			

* = Statistically significant; Exp = Experimental group; Cont = Control group; NA = Not Available

resulted in a moderate [54] to large magnitude of effects [57–59]. This is in line with our findings for specialized nursing competencies (moderate effect) and clinical competencies (large effect). These might result from the fact that case studies were given to the students, which might have given them the chance to engage in active experimentation and reflective observation, which could effectively facilitate learning and skill development and, ultimately, improve problem-solving abilities. Therefore, assigning task assignments should be dependent on the goals the instructor has in mind for the class. In support of this claim, Couto, Farhat, Geis, Olsen and Schvartsman [52] stated that a case study is better if the goal is to impart knowledge; on the other hand, high fidelity simulation may be the better choice if the goal is to impart both technical and non-technical skills. The ability to collaborate is one of the skills that nursing students may learn [53]. This is a process that calls for sharing, respect, and possibly even collaboration [55]. Nonetheless, because of the intricate structure of the healthcare system, students must be instructed in good communication with other co-professionals in the field as well as their duties and obligations once becoming qualified as nurses [58].

The studies showed small to large effects in improving problem-solving skills. Corroborating with similar studies, Kang and Yu [45] was able to achieved an improvement In problem solving ($t=4.32$, $p<.001$). Additionally, compared to standard care activities, there was an increase in problem-solving scores after using high-fidelity patient simulation [43]. Virtual simulation technology can assist in problem-solving, according to Chang, Jen and Yang [51], by enabling students to engage in learning exercises and brainstorming sessions that promote the development of problem-solving abilities. This is possibly so because students' involvement in digital systems can enhance their capacity for creative thought [60]. Individuals' inclinations and routines for problem-solving and making decisions may have an impact on their problem-solving processes [50]. In this way, individuals receiving virtual simulation interventions will be able to practice their problem-solving abilities in a safe and realistic clinical setting, which may help them adjust to a complex healthcare setting. However, preparation and briefing exercises before the simulation might boost participants' confidence in their ability to solve problems. Again, self-confidence in problem solving can improve learning efficiency, which in turn can promote clinical performance [61]. Students' confidence in problem solving was enhanced when they learned new information through pre-simulation preparation and instruction [62]. Therefore, when students see a real-life situation prior to clinical practice that is comparable to the situation presented in the simulation, their confidence in problem solving is enhanced [63].This could further be enhanced using situated learning which is an approach aids students in adjusting to challenging material and can enhance their ability to solve problems and learn [51]. Virtual technology adoption and integration into our nursing education systems is therefore crucial.

There was evidence of small to large improvement in student communication skills using virtual simulation technologies. This is in line with the findings of a systematic review, which found that employing simulation technology has the potential to enhance communication skills and may have advantages outside of the simulation facility (including the clinical settings) [64]. In particular, there was a large improvement in communication with nurses and other healthcare professionals in this study. Likewise research has also demonstrated that using simulation-based communication skills, healthcare professionals, including nurses, may develop their communication abilities [65]. It's common knowledge that effective communication is vital to providing patients with the greatest outcomes possible. Therefore, the most crucial aspect of providing healthcare may be communication, and this study found that having clear and open lines of communication with patients regarding their conditions reportedly had small magnitude of effect. Therefore, incorporating simulation technologies in training programs is important to foster student's communication abilities. Using simulation and tools/algorithms, which are currently employed in nursing education, can improve patient care and decrease unfavourable patient outcomes.

With the exception of the evaluation, which was reported to have a small effect size, the effects of all other phases of the nursing process are in the range of small to medium effect sizes. In the nursing process, the most important mechanism that helps is decision making [66]. Studies have shown that an educational program based on simulations of the nursing process can improve students' skills and provide a basic understanding of how the nursing process works. In addition, it is recommended that nursing students use interactive simulation-based learning experiences to improve their understanding of how theoretical ideas can be translated into reality [67]. It was also submitted that simulation-based nursing process might promote students professional competencies and or skills [47]. Therefore, computers, cellphones, and other technologies must be integrated with simulation and conventional teaching strategies for effective outcomes.

The use of simulation technologies can be associated with some negative effects, such as being overwhelmed by the technology, motion sickness in VR or traumatizing experiences among others. It is important to recognize that there were large differences between the included studies in terms of the different intervention types and comparison groups, different designs, different outcome measures and the dose (frequency, course and duration) of the intervention. All of this together could be responsible for the variations in the present results.

Limitations

This review included both RCTs and quasi-experimental studies with the latter offering lower quality evidence. The presented data did not allow a meta-analysis and the level of evidence may have produced bias in the results; hence, there is a need for high quality RCTs that could be used to confirm the effects of virtual simulation interventions. Regarding our conclusions on the influence of virtual simulation technologies on outcomes, heterogeneity in simulation types (different methodological didactic approaches), and distinct outcome measures also raise concerns about our findings. A process called simulation tries to mimic reality, even if it is not real. The fidelity of the simulator, the description of the scenario, and the environment all affect how realistic it is. Even with the most recent advancements in simulation models, human systems will never be perfectly replicated. So, when practicing virtual scenes on real-life scenarios, caution should be used.

The use of VR scenarios is a valuable, innovative supplementary teaching medium. However, it requires intensive preparation, support and evaluation. Since nursing is a relational profession, there seems to be no technology that can realistically replicate communication skills and haptics. Thus, more rigorous studies are needed to determine whether virtual experience can fully replace real-world clinical experience. However, the lack of rigorous long-term studies allows only limited conclusions to be drawn about how well this learning can be transferred to practice. Again, the inclusion of papers published solely in the English language may have limited the selection of research papers and compromised the generalizability of the results. Lastly, the different intervention components equally affected our confidence in the conclusion drawn from this review finding.

Implication for nursing & health policy

The use of virtual simulation technologies for students' clinical learning is valuable in the educational curriculum. To ensure effective integration of these technologies that might enhance students' competency in the delivery of patient-centered care in various healthcare settings; policy makers and nursing educators could consider integrating online simulations or teaching students' procedures online prior to real clinical scenarios to enhance their competencies.

Conclusion

Virtual simulations can improve the problem-solving process, communication skills, professional core competencies and nursing process skills. Therefore, to optimize the development of learning processes, nurse educators should consider the use of virtual learning technologies when revising curricula. Our overall confidence in the conclusions of this study is limited by the studies' quality and validity; a lack of high-quality RCTs and the heterogeneity of simulation types compromised our overall confidence. The results should be treated with caution. Finally, in order to increase the learning effectiveness of innovative virtual clinical learning modalities, the qualification of teachers/instructors must also be taken into account, as it is an important component alongside the pedagogical integration of technological possibilities.

Abbreviations

VS	Virtual stimulation
VR	Virtual reality
PRISMA	Preferred reporting items for systematic reviews & meta-analysis
RCT	Randomized controlled trial
PEDro	Physiotherapy evidence database
MΔ	Mean change
OSCE	Objective structured clinical examination

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Data availability
The datasets analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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