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REVIEW ARTICLE

# The effectiveness of virtual reality simulation as learning strategy in the acquisition of medical skills in nursing education: a systematic review

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## Abstract

**Purpose** This review was aimed to evaluate the effectiveness of virtual reality simulation as a teaching / learning strategy on the acquisition of clinical skills and performance, self-confidence, satisfaction and anxiety level in nursing education.

**Methodology** The Preferred Reporting Items for Systematic Reviews guidelines, using the PICO model that is based on an evidence-based practice process was matched. A total of twenty-three studies included six themes: performance skills ($n = 13$), self-confidence ($n = 8$), satisfaction ($n = 10$), anxiety level ($n = 3$), self-efficacy ($n = 4$), and knowledge ($n = 15$). Experimental randomised control trials and quasi-experimental studies from 2009 to 2019, conducted in English, were included. Nursing students ($n = 1797$; BSN, ADN, MSc, LPN) participated.

**Results and conclusion** This review was indicated that virtual reality simulation provides learning strategy to acquire clinical skills, improve knowledge acquisition, increase self-confidence, self-efficacy, and satisfaction level, and decrease anxiety levels among nursing students.

**Keywords** Motor skills · Nursing education · Nursing students · Simulation · Virtual reality

## Introduction

Clinical experience is a fundamental part of the practice of healthcare disciplines, especially in nursing education, which integrates theoretical with practical elements that comprise affective, cognitive, and also psychomotor fields of learning that promote the knowledge, skills, attitudes, and values that nursing students are required to learn [1, 2]. Acquisition of clinical psychomotor skills in nursing education is an integral part of being a nurse and providing safe nursing practices [3]. Nurse educators confront extensive challenges to supplying undergraduate nursing students with fit procedural nursing skills and relevant clinical learning experiences [4]; this is influenced by increased acceptance of student numbers, a shortage of nursing faculty, conflict for both laboratory time and clinical placement sites, intense competition from other healthcare professionals, and patient safety concerns on the part of the faculty and students [5]. Consequently, to promise the safety and quality of nursing education, there are appeals for educational reform in nursing schools. Students should have well-equipped laboratory sites where they can communicate with patient care before interacting with the actual patient by using innovative and interactive learning strategies that strengthen their skills in order to transfer knowledge to practice in a clinical application, including simulation experiences for students and game-based virtual reality [6, 7].

In nursing education, simulation is one of the interactive learning strategies in which students experience real-life situations without taking any risks, improves satisfaction and self-confidence, offers an active and safe learning environment, and proper feedback [8, 9]. During their undergraduate education, nursing students should be given the skills required to be able to think about their future role and to confront the challenges connected with their work responsibilities [10]. As maintained by the *Healthcare Simulation Dictionary*, virtual reality (VR) is a three-dimensional environment generated by computer that gives an immersion effect [11]. Virtual reality simulation (VRS) places

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learners in a key role through exercise of their complex cognitive thinking abilities, decision-making, effective, psychomotor control, performance, and communication skills [12, 13].

There is the necessity for a systematic review that examines the effectiveness of VRS as a learning strategy in acquisition of clinical nursing skills in nursing education and how this innovative learning strategy affects performance, learner satisfaction, learner efficacy, self-confidence, and anxiety levels in nursing students, in addition to knowledge retention and skill acquisition that this review has included and deemed distinct.

The aim of this study is to evaluate the effectiveness of VRS as teaching/learning strategy with respect to acquisition clinical skills and performance, satisfaction, self-confidence, and anxiety level in nursing education.

## Method

### Study questions

The Population, Intervention, Comparison and Outcomes (PICO) model was considered appropriate [14], which in this review included the following: P, students nurse; I, virtual reality simulation; C, manikin simulation/face-to-face clinical practice; O, nursing skill acquisitions, satisfaction, performance, self-confidence, and anxiety, learning strategy.

Including these terms led to the following question:

1. How does VRS impact on clinical nursing skills as a learning strategy for nursing students?
2. How does virtual reality simulation affect satisfaction, self-confidence, self-efficacy, and anxiety among nursing students?

### Data sources

Studies were identified through seven databases, including Cochrane Library, PubMed, CINAHL, EBSCO host, Science Direct, LIVIVO, and OVID (January 2020). The limited timeframe was from 1 January 2009 to 31 December 2019. The main search strategy combined terms and keywords including "virtual reality," "virtual reality simulation," "nursing students," "nursing education," "learning/teaching strategy," and "nursing skills." Searches were limited to articles in English.

### Study selection

Inclusion criteria included the following: (1) nursing students, (2) experimental studies or pre-post quasi-experimental, (3) virtual reality related to nursing, and (4) a primary outcome measure (i.e., acquisition of nursing skills, learning strategy, cognitive skills [knowledge]) and a secondary outcome (i.e., satisfaction, performance, self-efficacy, self-confidence, and anxiety). Exclusion criteria included the following: (1) basic information not complete to extract data, (2) studies not in English, and (3) studies not include nursing students.

### Data extraction, quality assessment, and synthesis

We followed Boland's (2017) model of data extraction, table construction, and analysis using narrative synthesis. Data were aggregated, and the quality of each study was assessed according to the *Cochrane Handbook for Systematic Reviews* tool/guidelines (Version 5.1.0) [15]. Figure 1 shows the study selection process. Studies were sourced by electronic retrieval, then uploaded to a reference management database; thereafter, duplicates were eliminated.

## Results

Twenty-three studies met inclusion criteria. Database searches were carried out between 4 January 2020 and 12 January 2020. Table 1 details our results. VR technology consisted of a variety of devices and platforms. Some technologies were developed by faculty members/researchers, while others are commercially available. Several studies were single site ($n=9$), while the majority include two or more data collection sites ($n=14$). Studies used Web conferencing technology, computer-assisted learning modules, games, virtual IV pumps, haptic devices, avatars, and head mounted displays.

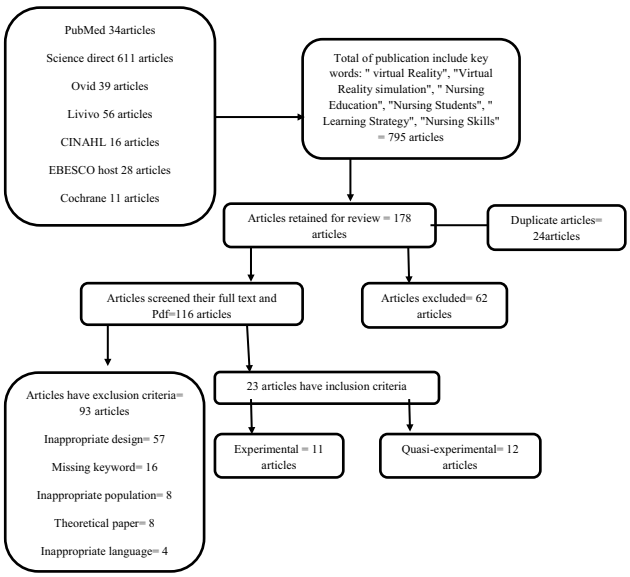


**Fig. 1** Database flow diagram

**Table 1** Summary of experimental studies and quasi-experimental studies

| Study design | Author (year) | Application | Population | Purpose | Outcome studied | Measurement tool | Effect estimate or difference obtained |
|---|---|---|---|---|---|---|---|
| Experimental (pretest–posttest) | Rossler et al. [16] | Virtual Electro surgery Skill Trainer (VEST) simulator | Pre-licensure baccalaureate nursing students ($N=20$)<br>Control = 10<br>Experimental = 10 | The effectiveness of the on OR fire safety skills among pre-licensure nursing students | • Knowledge<br>• Performance skills | • Pencil-and-paper Fire Safety Evaluation pretest and posttest<br>• Perioperative Performance Evaluation Tool for Nursing | No significant in knowledge<br>In control group ($P=0.18$),<br>In intervention group ($P=0.13$)<br>Increase in performance skill ($P=0.001$) |
| Experimental (RCT) | LeFlore et al. [18] | Virtual Pediatric Patients (VPPs)<br>Virtual Pediatric Unit (VPU) in pediatric course | Senior baccalaureate nursing students ($N=93$)<br>Control = 47<br>Experimental = 46 | The effectiveness of a virtual patient trainer for the achievement of learning outcomes | • Knowledge acquisition<br>• Knowledge application | • Objective Structured Clinical Examinations (OSCEs)<br>• Multiple-choice test (a written test) | Increase knowledge acquisition in intervention group ($P=0.004$)<br>More timely performance of knowledge application in intervention group ($P=0.001$) |
| Experimental (RCT) | Padilha et al. [22] | Case-based learning approach, with a clinical virtual simulation | Second year of nursing students (BSN) ($N=42$)<br>Control = 21<br>Experimental = 21 | The impact of clinical virtual simulation in nursing education as a learning strategy | • Knowledge retention<br>• Level of knowledge across time<br>• Learner satisfaction<br>• Self-efficacy | • True or false and multiple-choice test<br>• The Learner Satisfaction with Simulation Tool (Duarte H,2015)<br>• The General Self-Efficacy Scale (Schwarzer R, 1995) | Increase knowledge retention (posttest) ($P=0.001$), and 2 months later ($P=0.02$) in experimental group<br>There are significant for time indicating ($P<0.001$), and for interaction term time × group ($P=0.02$) in experimental group<br>Increase learner satisfaction ($P<0.001$) in experimental group<br>No significant difference in self-efficacy ($P=0.9$) |

**Table 1** (continued)

| Study design | Author (year) | Application | Population | Purpose | Outcome studied | Measurement tool | Effect estimate or difference obtained |
|---|---|---|---|---|---|---|---|
| Experimental (pre–post-test and focus groups) | Verkuyl et al. [24] | Virtual game simulation (VGS) in debriefing methods | First-year nursing students (BSN) ($N=200$)<br>Self -debrief group ($n=61$)<br>person group ($n=61$)<br>virtual group ($n=78$) | Examine various debriefing methods for Participants completed virtual gaming simulation | • Knowledge<br>• Self-efficacy gain<br>• Debriefing experience | • Self-efficacy survey (Maher and Atack, 2011)<br>• Knowledge test (Kudere Richardson 20)<br>• Debriefing experience scale (Reed, Andrews, & Ravert, 2013) | In self-efficacy, there is statistically significant difference in the pre-SE between groups ($P=0.013$)<br>No statistically significant difference in the post-test ($P=0.142$)<br>Between groups increase in the pre-SE scores<br>Within-group increase SE posttest, students in virtual debrief group made (7.5/45points)<br>In knowledge test,<br>In pre ($M=71/100$) in the post ($M=81/100$) for all groups<br>Between the groups, no statistically significant difference in the pre- or the post-knowledge test scores ($P\geq 0.05$)<br>Within groups, increase on their knowledge posttest scores by one point for each group<br>In the debriefing experience, highest debriefing score in virtual group ($M=87.7/100$) |

**Table 1** (continued)

| Study design | Author (year) | Application | Population | Purpose | Outcome studied | Measurement tool | Effect estimate or difference obtained |
|---|---|---|---|---|---|---|---|
| Experimental (RCT) | Bayram and Caliskan [29] | Game-based virtual reality phone application suctioning a tracheostomy tube | First-year nursing students ($N=86$)<br>Control = 43<br>Experimental = 43 | Define the effect of a game-based virtual reality phone application on tracheostomy care education | • Knowledge<br>• Performance skill<br>• Performance time | • Tracheostomy Care Knowledge Test<br>• Objective Structure Clinical Examination for a skill assessment Tracheostomy Care Skill Checklists | In first and last knowledge, no significant differences between groups ($P>0.05$), and increased in the last knowledge in both groups<br>Time to conduct in the control group longer than the experimental group<br>In the first skill performance, increased in inner cannula cleaning skill and peristomal skin care of the students in the experimental group<br>In the last skill performance, increased the inner cannula cleaning skill and peristomal skin care of the students in the experimental group |

**Table 1** (continued)

| Study design | Author (year) | Application | Population | Purpose | Outcome studied | Measurement tool | Effect estimate or difference obtained |
|---|---|---|---|---|---|---|---|
| Experimental (RCT) | Jung et al. [30] | Using VR/Haptics intravenous injection (IV) Simulation (IV sim) | First-year nursing students ($N=114$) 3 group each one = 38 | Educational effectiveness of practical exercises (PE) using intravenous (IV) Simulation incorporating virtual reality | •Performance<br>• Anxiety<br>• Satisfaction | • Trait State anxiety scale (Spieberger's, 197) using the Visual Analogue Scale (VAS)<br>• Evaluate performance procedure<br>• Questionnaires to investigate the effectiveness of and satisfaction rate with the training aid | Anxiety level decreased in the three groups after venipuncture<br>In performing injections and satisfaction level, the highest score for the success retain the students used a VR/haptics (IV sim) ($P=0.014$) and completed the venipuncture task the fastest performance time. ($P=0.007$) |
| Experimental | Farra et al. [13] | Virtual reality simulation in disaster training | 2nd-year Associate Degree During (AND) students ($N=41$)<br>Control = 20<br>Experimental = 21 | Examined the effectiveness of virtual reality disaster simulation of disaster training in nursing students | • Knowledge acquisition and retention | • The knowledge assessment tool | VRS increased knowledge score; pre-knowledge, the immediate post-assessment, the 2-month assessment ($P<0.0001$) |
| Experimental (RCT) | Reinhardt et al. [28] | High-fidelity computer-assisted simulation technology IV Insertion (Virtual haptics device) | First year baccalaureate nursing students ($N=94$) | Determine whether exposure to the high-fidelity simulation device before or after practice with the task trainer | • Self confidence<br>• Skill performance | • Skills Assessment Checkoff Tool<br>• Self-Reported Confidence Survey Tool<br>• Follow-up questionnaire | No significant difference<br>Between the student's skills score and the confidence level score ($r=0.165$, $P=0.18$)<br>In skill scores, experimental ($P=0.7$), and in the control ($P=0.5$)<br>In confidence score, experimental ($P=0.6$) and the control ($P=0.4$) |

**Table 1** (continued)

| Study design | Author (year) | Application | Population | Purpose | Outcome studied | Measurement tool | Effect estimate or difference obtained |
|---|---|---|---|---|---|---|---|
| Experimental | Verkuyl et al. [25] | Virtual Game Simulation in pediatric postoperative appendectomy care | Second year baccalaureate nursing students (BSN) ($N=47$)<br>Control = 23<br>Experimental = 21 | Compare a VGS with the traditional laboratory simulation concerning learning outcomes | • Knowledge<br>• Self-efficacy<br>• Satisfaction | • Pediatric Skills SE Survey (Maher & Atack, 2011)<br>• A pediatric nursing care knowledge test<br>• Simulation Satisfaction Survey( Ryan, Campbell, and Brigham, 1999) | In self-efficacy and posttest knowledge, increased in experimental group;<br>In satisfaction, no significant differences between the control ($M=92/100$) and experimental group ($M=92.8/100$) ($P>0.05$) |
| Experimental (RCT) | Cobbett and Snelgrove-Clarke [34] | Virtual clinical simulation (VCS) in maternity course | Third-year baccalaureate nursing students (BSN) ($N=56$)<br>Experimental = 27<br>Control = 28 | Evaluate the effectiveness of two simulation for maternal newborn clinical scenarios (preeclampsia and Group B Streptococcus [GBS]) | • Knowledge<br>• Anxiety level<br>• Self-confidence<br>• Perceptions (self-reported) | • 10 multiple-choice questions per clinical simulation<br>• Nursing Anxiety and Self-Confidence with Clinical Decision Making Scale (NASC-CDM) (White, 2011)<br>• Clinical Simulation Completion Questionnaire | No significant difference in scores for face to face and virtual clinical simulations ($M=4.12$, SD = 1.54)<br>In students' knowledge ($P=0.09$) and in students' self-confidence ($P=0.059$)<br>In anxiety level, higher statistically significant effect in the VCS group<br>In perceptions, students did not preferred VCS because technical issues that affect negatively on learning process |

**Table 1** (continued)

| Study design | Author (year) | Application | Population | Purpose | Outcome studied | Measurement tool | Effect estimate or difference obtained |
|---|---|---|---|---|---|---|---|
| Experimental | Luctkar-Flude et al. [31] | Online virtual IV pump educational | 3rd-year of undergraduate nursing students (BSN) ($N=43$)<br>Control = 26<br>Experimental = 17 | To evaluate the effectiveness of using online virtual IV pump as a learning strategy with the educational module | • Performance skill<br>• Performance time<br>• Self-confidence<br>• Satisfaction | • IV Pump Skills Self-Confidence Survey (developed by faculty)<br>• Virtual IV Pump Educational Module Satisfaction Survey<br>• IV Pump Skills Performance Checklist | No difference significant<br>In self-confidence, mean higher in the experimental group than the control group ($M=40.88$, SD = 5.52);<br>In satisfaction, the mean score ($M=39.06$, SD = 5.18)<br>In performance, higher in the experimental group ($M=28.12$, SD = 3.77) and longer (14.62 min) to perform all IV pump skills than those in the control group<br>On the skill of programming a continuous medication infusion higher in the experimental group ($M=10.00$, SD = 2.70)<br>There were significant correlations between learner self-confidence and performance scores; students with higher self-confidence scores had higher secondary medication scores and higher total performance scores |

**Table 1** (continued)

| Study design | Author (year) | Application | Population | Purpose | Outcome studied | Measurement tool | Effect estimate or difference obtained |
|---|---|---|---|---|---|---|---|
| Quasi-experimental | Ismailoglu and Zaybak [27] | IV catheter insertion by using virtual intravenous simulation | Second-year bachelor's nursing students(BSN) ($N=65$)<br>Control = 32<br>Experimental = 33 | Compare the effectiveness of virtual intravenous simulation with plastic arm model in teaching intravenous catheter insertion skills to nursing students on learning outcome | • Knowledge<br>• Performance (psychomotor) skills<br>• Self-confidence<br>• Satisfaction<br>Fear Symptoms | • Intravenous Catheterization Knowledge Assessment Form<br>• Intravenous Catheterization Skill Checklist<br>• Visual Analog Scale<br>• Fear Symptoms Scale | No significant difference between both groups:<br>Of pretest and posttest knowledge scores ($P>0.05$);<br>Self-confidence scores ($P=0.597$);<br>There was significant difference in scores between groups:<br>In psychomotor skills score higher in the experimental ($P=0.000$)<br>Satisfaction score higher in the experimental group<br>Decreased Fear Symptoms Scores in the experimental |
| Quasi-experimental | Farra et al. [17] | Virtual reality simulation (VRS) in the disaster-specific skill of decontamination | Senior nursing baccalaureate students ($N=90$)<br>Control = 45<br>Experimental = 45 | Determine the effectiveness of teaching the disaster-specific skill of decontamination | • Performance<br>• Knowledge<br>• Self-efficacy | • Emergency Preparedness Information Questionnaire (EPIQ)<br>• 20 multiple choice questions from the FEMA IS-346: An Orientation to Hazardous Materials for Medical Personnel examination (FEMA, 2013)<br>• Decontamination Checklist | In experimental group decreased performance:<br>Shorter period of time VRS skill;<br>Increased levels of satisfaction<br>No significant differences:<br>In self-efficacy ($P=0.172$), but increased in experimental group knowledge ($P=0.631$) |

**Table 1** (continued)

| Study design | Author (year) | Application | Population | Purpose | Outcome studied | Measurement tool | Effect estimate or difference obtained |
|---|---|---|---|---|---|---|---|
| Quasi-experimental | Smith et al. [23] | Two levels of immersive VRS in the skill of decontamination | senior baccalaureate nursing students ($N=197$)<br>Group A (immersive VRS) = 59<br>Group B (keyboard and mouse) = 58<br>Group C (control group) = 55 | Evaluate the impact of immersive VRS to the learn skill of decontamination on learning outcome | • Knowledge (cognitive learning)<br>• Performance<br>• Performance time | • Decontamination Checklist<br>• Cognitive exam, revised from the FEMA IS-346: An Orientation to Hazardous Materials for Medical Personnel to meet the objectives of the study ([FEMA], 2013)<br>• Focus group questions | No significant differences<br>Between the intervention groups based on cognitive test scores or time to completion; cognitive test score (pre/post/6 months)<br>Performance score (post/6 months)<br>Time to complete the skill (post/6 months) ($P>0.05$)<br>Cognitive scores increased immediately after treatment and decreased at the retention measurement point 6 months later<br>Performance scores higher immediately posttraining than at 6 months posttraining |
| Quasi-experimental | Vidal et al. [26] | VRS in phlebotomy skills | 2nd-year associate degree nursing students($N=73$)<br>Control = 27<br>Experimental = 46<br>During 2009/2010 | Evaluate the efficacy of the simulated limbs and CathSim system for phlebotomy training | • Performance<br>• Performance time | • Questionnaire assess the sociodemographic characteristics of respondents<br>• Phlebotomy performance checklist | 3 performance metrics are significant: The group exposed to the VRS (experimental) produced less pain factor ($P$ 0.16), fewer hematomas ($P$ 0.00), and fewer reinsertions ($P$ 0.00) compared with the control group<br>The VR group had longer duration in applying the catheter and longer time to complete the procedure |

**Table 1** (continued)

| Study design | Author (year) | Application | Population | Purpose | Outcome studied | Measurement tool | Effect estimate or difference obtained |
|---|---|---|---|---|---|---|---|
| Quasi-experimental | William et al. [36] | Used VRS in phlebotomy skills | 2nd-year associate degree nursing students ($N=62$)<br>Control = 33<br>Experimental = 29<br>During 2011/2012 | Compare the differences in the skill performance of phlebotomy between a two groups on actual patient | • Performance<br>• Performance time | • Questionnaire assess the sociodemographic characteristics of the respondents<br>• Phlebotomy performance checklist | No significant differences in results in the various performance metrics in comparing the control and experimental groups<br>No significant difference, the number of reinsertions, in the two groups had the same performance metric with the highest *P* value<br>The experimental group showed Positive remarks were given by 65.5% in their exposure to their actual practice on the clients<br>No significance, the total time to complete the procedure for both groups had the lowest *P* value |

**Table 1** (continued)

| Study design | Author (year) | Application | Population | Purpose | Outcome studied | Measurement tool | Effect estimate or difference obtained |
|---|---|---|---|---|---|---|---|
| Quasi-experimental | Bryant et al. [21] | Virtual clinical simulation VSC online Advanced Health Appraisal course | Master of Science in Nursing students ($N=65$) | Evaluate the impact of the virtual clinical simulation on student clinical proficiency and to evaluate the virtual clinical experience as a teaching strategy | • Perception Performance<br>• Satisfaction<br>• Self-confidence | •The Integrated Performance Proficiency Rating Tool (IPP score)<br>•The National League of Nursing Simulation Design Scale (NLN score)<br>(a) Simulation design scale<br>(b) Educational practices in simulation scale<br>(c) Student satisfaction and confidence in learning scale | No significant difference:<br>In course grades ($z=-0.64$, $P=0.52$);<br>performance proficiency ($z=-0.87$, $P=0.38$);<br>Satisfaction with current learning ($z=-0.93$, $P=0.35$);<br>Self-confidence in learning ($z=-0.32$, $P=0.75$) |
| Quasi-experimental (three-group, posttest-only) | Wright et al. [33] | Virtual simulation (vSim) on adult health course | Undergraduate nursing students ($N=103$)<br>Control = 35<br>Intervention 1 S = 32<br>Intervention 2 NS = 36 | Evaluate the effectiveness and student's satisfaction of vSim for nursing in an Adult Health Nursing course | • Knowledge<br>• Satisfaction<br>• Self confidence | • Participant satisfaction with the vSim for nursing experience was evaluated using an eight-item questionnaire created by faculty<br>• The Student Evaluation of Medical-Surgical Nursing vSim for Nursing (SEMSNV)<br>• Both colleges used Brunner and Suddarth's Textbook of Medical-Surgical Nursing 13th Edition (Lippincott Williams & Wilkins, Philadelphia, PA) | No significant difference,<br>In the examination scores ($P=0.077$);<br>The postsimulation examination score ($P=0.433$)<br>Both simulation groups (group 1, $M=59.03$; group 2, $M=58.06$) higher than the control group ($M=55.31$)<br>76% of the participants agreed or strongly agreed that vSim for nursing increased their confidence in caring for real patients<br>Participants were highly satisfied with vSim for nursing |

**Table 1** (continued)

| Study design | Author (year) | Application | Population | Purpose | Outcome studied | Measurement tool | Effect estimate or difference obtained |
|---|---|---|---|---|---|---|---|
| Quasi-experimental | Smith et al. [19] | Virtual reality simulation (VRS) on the skill of decontamination | Senior baccalaureate students (BSN) ($N=108$)<br>Control = 51<br>Experimental = 57 | Examine the longitudinal effects of virtual reality simulation (VRS) on learning outcomes | • Cognitive knowledge<br>• Performance Skill<br>• Performance Time | • Performance rubric that include behavioral items<br>• Multiple-choice test consisting of 20 questions | In cognitive test, over time and improvement on the cognitive test from the pretest($M=9.2$) to the posttest ($M=14.60$);<br>In performance, differed significantly over time ($P=0.016$)<br>On the pretest, the control group performed better more than VRS group<br>On the posttest, VRS group performed better immediately after training ($P=0.041$)<br>At 5 to 6 months posttreatment, VRS group showed a lower mean performance score retention period (11.34 vs. 11.93)<br>In performance time<br>Main effect of test time ($P<0.001$)<br>The VRS group faster both immediately post (11.4%) and at 5 months following training (6.8%) |

**Table 1** (continued)

| Study design | Author (year) | Application | Population | Purpose | Outcome studied | Measurement tool | Effect estimate or difference obtained |
|---|---|---|---|---|---|---|---|
| Quasi-experimental (pretest-intervention-posttest comparison group) | Dubovi et al. [4] | PILL-VRS | Second-year baccalaureate nursing students ($N=129$)<br>Control = 47<br>Experimental group = 82 | Demonstrate how the VR environment can integrate learning theoretical knowledge into practice, we examined a particular skill within nursing education; medication administration | • Knowledge learning<br>• Performance skills<br>• Presence score | • The PILL-VR environment for medication administration<br>• MAP knowledge questionnaire<br>• Presence questionnaire<br>• Students' worksheets and video recordings | No significant differences ($P=0.28$)<br>Increased conceptual and procedural knowledge learning gains, with a strong effect size (Cohen's $d=0.91$)<br>showed that less time (in minutes) was taken in the second scenario (B) (median = 0.75) than in scenario A (median = 4.0), $P<0.05$<br>improved performance reflected in fewer errors:<br>•during scenario A, a median of 3.0 mistakes was performed, which was then reduced to none in scenario B with a median of 0 mistakes, ($P<0.05$).<br>increased learning of the medication sequence was achieved in the experimental group |

**Table 1** (continued)

| Study design | Author (year) | Application | Population | Purpose | Outcome studied | Measurement tool | Effect estimate or difference obtained |
|---|---|---|---|---|---|---|---|
| Quasi-experimental (a posttest-only) | Ausburn et al. [20] | Using VR desktop of surgical operating room environments | Licensed Practical Nursing (LPN) students ($N=18$) | Compare the differential effects of VR and traditional still image presentations of surgical operating room environments to students with high- and low-visual perceptual styles | • Performance and perception<br>• Self confidence<br>• Knowledge<br>Performance time | • The scale for confidence<br>• The scale for difficulty | Between perceptual type and presentation method; the High-Visuals did better with the VR treatment ($M=2.20$) than with the still image treatment ($M=1.00$)<br>In interaction level ($P=0.07$);<br>Increased visual cognitive load in the VR treatment<br>The High-Visuals worked less time on the test after seeing VR ($M=593$ s) than after seeing still images ($M=750$ s)<br>No significant difference<br>In confidence score ($P=0.08$); the still image treatment produced greatest level of confidence ($M=3.00$) than the VR treatment ($M=2.44$)<br>The HVs felt slightly more confident with VR ($M=3.00$) than with still images ($M=2.75$)<br>For the perceived task difficulty score ($P=0.09$);<br>The LVs perceived the task to be more difficult ($M=3.56$) than the HVs ($M=3.00$) |

**Table 1** (continued)

| Study design | Author (year) | Application | Population | Purpose | Outcome studied | Measurement tool | Effect estimate or difference obtained |
|---|---|---|---|---|---|---|---|
| Quasi-experimental (after-only experimental) | Smith and Hamilton [32] | Virtual reality simulation Foley catheter skill | Students of associate's degree in nursing (AND) ($N=20$)<br>Each group = 10 | Evaluate the effectiveness of virtual reality simulation that designed to support Foley catheter skill | • Performance level<br>• Performance time<br>• Level of preparedness | • Demographic questionnaire<br>• Log sheets (log of practice time; began–end)<br>• Skills Evaluation Tool<br>• Visual Analog Perceived Preparedness Scale | No significant difference:<br>All of performance scores successfully completed in the experimental group<br>In level of preparedness ($P>0.05$)<br>In overall performance scores ($P>0.05$)<br>Faster performance time ($P>0.05$)<br>In virtual simulation models ($M=31.10$, SD = 20.99) and nonhuman models ($M=125$, SD = 66.08) |
| Quasi-experimental (only posttest) | Kardong-Edgren et al. [35] | VR game using Oculus Rift devised to allow the practice of placing a urinary catheter in a virtual patient | undergraduate juniors and senior nursing students and nursing faculty ($N=31$) | Evaluate the usability of a VR game system for sterile catheterization practice | • Satisfaction<br>• Self confidence<br>• Perceptions | 1. SUS (it consists of a 10-item scale with questions about effectiveness, efficiency, and satisfaction with a system such as software, hardware, and applications)<br>2. User responses system (URS) | The System Usability Survey (SUS) response ratings were (64.03)<br>75% of participants rated the game as positive overall on the URS<br>77% would like to use the system frequently<br>85% thought the system was easy to use<br>80% agreed or strongly agreed they would learn to use the system quickly |

## How does VRS impact on clinical nursing skills for nursing students?

### Using VRS as a learning strategy in skill acquisition

Fourteen studies (56.5%) examined VRS as a supplemental learning tool for skill acquisition as (IV, suctioning, decontamination, phlebotomy, administering medication, Foleys catheter skills). For details on the application of VRS, see Table 1.

Six studies showed that VRS allows students to act several roles in different settings [4, 13, 16–19], and seven studies showed that VRS enhances the role of students in debriefing, orientation and interacting with a virtual environment, self-reflection, and clinical reasoning [20–26]. On the other hand, four studies showed the effectiveness of performing skills on actual patients after using various VRS techniques [26–28].

Twelve (92%) studies showed an improvement in skill performance of nursing students after using VRS [4, 16, 19, 20, 23, 26, 27, 29–33], while three (23%) studies indicated a decreased effect of VRS on performance scores and perceptions of students because of technical issues [17, 34, 35]. On the other hand, 23% showed no difference between VRS methods and face-to-face/manikin simulation [21, 28, 36]. In performance time, six (46%) studies showed the use of VRS in various skills improved skill performance and an enhanced use VR-based system to supplement face-to-face/manikin simulation may be the optimal training program to complete skills efficiently [4, 19, 20, 23, 30, 32]. Vidal et al. and Luctkar-Flude et al. explained that using VRS takes longer to acquire skills, and the order of procedural steps is important in teaching psychomotor skills.

### The effectiveness of VRS on cognitive skills (knowledge and retention)

Fifteen (65%) of twenty-three studies examined that VRS can improve student learning or their knowledge. In cognitive context, six studies showed that VRS increase acquisition and retention of knowledge [4, 13, 16, 18, 22, 25]. Furthermore, VRS enhances development, gained, and applying knowledge [13, 19, 23, 27, 29]. In the affective domain, seven studies found realistic VRS experiences providing knowledge about caring, interactions, allowed for feedback on accessible engagement enjoyable game, and students' attention [13, 17, 18, 20, 23, 33, 34], while other studies showed no difference in knowledge after 5 months [4, 19]. Seven studies showed no difference when using VRS as compared to face-to-face/manikin simulation of acquisition, application, and learning knowledge, and increased knowledge in both groups in which VRS is considered as a supplemental tool alongside face-to-face/manikin simulation [16, 17, 24, 27, 29, 33, 34].

## How does VRS affect satisfaction, self-confidence, self-efficacy, and anxiety among nursing students?

### Nursing student's satisfaction

Eleven studies (48%) examined learner satisfaction after VRS use. Ten studies showed an increase in learner satisfaction [20, 22, 24, 25, 27, 30–33, 35]. One study that compared VRS with face-to-face/manikin simulation showed no difference in satisfaction with the learning experience [21].

### Nursing students' anxiety level

Three (13%) studies examined outcomes related to anxiety levels among nursing students ($n=235$). Two studies showed VRS can be a reliable and effective teaching/learning strategy to reduce anxiety levels, and fear symptoms among students [27, 30]. On the other hand, a study by Cobbett and Snelgrove-Clarke showed VRS rise anxiety levels among students.

### Self-confidence

Eight (35%) studies examined outcomes related to self-confidence resulting from VRS. Three studies showed that VRS can increase self-confidence [20, 33, 35], and five studies found that VRS compared to face-to-face/manikin simulation does not affect self-confidence [21, 27, 28, 31, 34], although studies of Luctkar-Flude et al. and Ismailoglu and Zaybak showed higher self-confidence in VRS than face-to-face/manikin simulation.

### Self-efficacy

Four (17%) studies examined outcomes related to self-efficacy. Three studies showed VRS increased self-efficacy among nursing students using various strategies [17, 24, 25]. The study of Bandura showed no differences in perception of self-efficacy among students because simulation strategy used only one intervention with one class, in line with self-efficacy theory; self-efficacy perception is caused by interaction of different variables over time [37].

# Discussion

## Knowledge/skill performance/performance time

In this review, although methods employed varied among studies, 53% showed that VRS reinforces knowledge acquisition and 92% showed that it improves skill performance. Knowledge is examined through focusing on several cognitive contexts, in which VRS allows acquisition of knowledge

through learning experience and error training that is a valuable part of gain information for nurse students who is serving feedback for their actions [4]. In addition, VRS had positive effect on retention of knowledge through replicating actual areas into realistic scenarios at any time such as creating variety of models for disaster situations, and using virtual patients in a case-based learning approach [19, 22, 38]. On the other hand, VRS assists transfer of knowledge through conveying theoretical knowledge to practice by applying VRS in various programs education and used game-based virtual reality phone applications such as role perioperative team, tracheostomy care, and IV pump skills [16, 29, 31].

Furthermore, various studies showed that VRS play vital role in promoting active learning including first, students take an active role when they played individually, which supports Kolb's theory—when learners have engaged in active experimentation, learning will be most effective [39]. Second, VRS integrating exciting, fun, and motivating in the learning process helping students' problem-solving and critical thinking that reduce anxiety. Third, VRS helps to provide feedback and reflection especially with a formative assessment helping knowledge retention [18, 24, 25, 30, 33]. On the other hand, VRS enhances conceptual and procedural learning through bridging gap between theoretical and clinical skills that occur in nursing education, let students gain information by using auditory/visual senses [4].

Moreover, there is another study that showed the importance of VRS in a classroom instructional setting during visualizing skills, in which VRS assist retention of mental image, explore real-world interactions for learners, instructional variables, and tasks [20], which agreed with a study of [40] that indicated students learn through rules of doing and being.

This review showed that VRS was used in various learning strategies such as a case study, several contexts such as specific scenarios in safety education, pediatric courses, and disaster training, and psychomotor skills that demonstrated improvement in the performance of various skills included tracheostomy tube, IV catheterization, medication administration, and decontamination skills. Consequently, VRS showed improvement in decision-making and transfer of safer practices that allow experiential learning [16, 18, 19, 23, 25, 38], which is compatible with the studies of [41].

On the other hand, some studies showed that no variations between both VRS and face-to-face/manikin methods used on knowledge level and performance skill, related to several factors such as the following: (1) providing relevant theoretical knowledge and then performed procedure steps as many times; (2) participants may be exposed to same instructional content or test itself; (3) constant program planning and resource; and (4) technical and game progression issues caused by using this type of educational game and training equipment for the first time [17, 21, 25, 27–29, 34, 36]. Thus, it can be concluded that neither the VRS nor the face-to-face/manikin method is considered perfect in and of itself or totally offers the procedure performed on an actual patient [30, 36]. In addition, it may be provided students with an opportunity to contextualize and reinforce their theoretical knowledge by learning through experience, which is compatible with the studies of [41].

With respect to performance time, 46% of studies showed students performed tasks faster through VRS compared to face-to-face/manikin method that related to realistic conditions which allow students to repeat procedure after sufficient practice time, and extend students' preparedness level to perform skill [4, 19, 20, 23, 26, 30, 32]. In contrast, Succar et al. showed that using VRS caused students to spend greater performance time than when using face-to-face/manikin simulation, which may be considered a gap between completing virtual skills and real skills on account of the immaturity of VR technology [42]. Thus, that does not mean that learning outcomes with VRS decreased, but the use of a VR-based system may be a supplement to face-to-face/manikin simulation is the optimal program for training nurses [43].

### Satisfaction/self-confidence/self-efficacy/anxiety

VRS is enhanced satisfaction among students in performing clinical skills through feelings of usability, usefulness, and providing positive feedback [22, 30, 32, 35]. Curtin et al. showed improved learner satisfaction through enhancing their knowledge, learning goals and outcomes, feeling that preparation was both convenient and excellent, as is compatible with the study of [44]. And, this may contribute to motivation, improved clinical skills, and reduced time spent in education by promoting self-reflection activities [21, 27]. The study of Verkuyl et al. showed learners' satisfaction related to increasing understanding, challenging knowledge, and critical thinking, allowing for reflection in a realistic environment. In addition, they can do practical skills at any time anywhere if they have VRS devices such as Oculus Rift which allow them to provide feedback [24]. Also, study of Ausburn et al. showed increased satisfaction between learners and educators through found strong enthusiasm to used desktop VR, which they recommended to design, and implementation/distribution of functional desktop VR [20]. One study showed learner dissatisfaction when using VRS compared to face-to-face/manikin simulation because of some technical issues, e.g., students could not perform skills effectively [34].

In this review, three studies showed that VRS increased self-efficacy rather than face-to-face/manikin simulation [17, 24, 25], and three studies showed that VRS increased

self-confidence [20, 33, 35]. This is in agreement with the review of Foronda. In self-confidence there is no difference when participating with face-to-face/manikin simulation versus VRS in clinical practice scenarios such as apply two maternal new-born clinical simulation scenario [34], which concurs with the studies of [45] that conclude that VRS integrates learning principles constructivism, through enhancing self-directed learning in a realistic setting while enabling student learning and supporting their confidence.

Two studies in this review showed that VRS may be an effective learning strategy that reduces nursing students' anxiety levels and fear symptom among students who used a virtual intravenous simulation than among those who used plastic arm models [27, 30], congruent with Nielsen and Harder [46] study that recommendations may reduce student anxiety during simulation such as educators being supportive and friendly, providing sufficient instructions to environment and simulation roles, and planning nursing care as a team. One study showed that students in face-to-face simulations have been more comfortable because they had prior exposure to the simulation lab, and technology surrounding VRS caused the rise in anxiety levels [34].

### Technical issues

Four (17%) studies demonstrated that VRS has technical issues that may have an influence on learning outcomes. Kardong-Edgren et al. showed that students are comfortable with technology which was associated positively with simulation scores ($P = 0.004$). Another study showed that students preferred face-to-face simulation compared to VRS with the reason related to technological issues such as a slow online program [34]. Additionally, a study of Ausburn et al. reported that there is no technical problem with VRS in a classroom setting, and the issues with channel and cognitive overload may recede by providing adequate time for training and learning, and exploring VRS details when using instructional VR in complicated graphic environments like equipment, laboratories, and facilities interiors.

## Limitations

There are several limitations to this review. First, we were not able to perform subanalysis because of restricted data in primary studies. Second, results could differ if other databases and grey literature were included. There is known bias when only published studies are reviewed. Third, we did not perform hand searches of relevant journals. Finally, results would differ if the population of interest extended beyond nursing students.

## Conclusion

VRS can be considered a useful learning strategy and a beneficial choice for promoting skill acquisition, retention of knowledge, and enhancing effective learning strategies for learners. Furthermore, the combination of VRS into nursing curriculum content is an appropriate strategy for providing additional methods for skill acquisition. It also has a positive impact on self-confidence, self-efficacy, and satisfaction, and decreases anxiety levels among nursing students. On the other hand, further studies suggest improving our understanding of VRS's effects on the acquisition of skills for nursing students to improve their performance. Likewise, it is essential to realize not only whether this type of intervention is efficient but also whether it is agreeable to nursing educators and learners. Therefore, there is a need for research to acquire knowing and understanding about how and why this approach to learning might be utilized.

## Recommendations

Future research should look at a diversity of healthcare professionals to ensure results can widely be generalizable, performing longitudinal studies for students after a completed experience of VRS to determine if knowledge acquired translates into changes in clinical practice through evaluating cognitive, affective, and psychomotor. Furthermore, advanced studies are essential on the use of VRS in nursing education and training.

### Declarations

**Conflict of interest** The authors declare no competing interests.

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