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Review Article

Does the Use of Virtual Reality Affect the Performance of Undergraduate Nursing Students? A Scoping Review

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Abstract

Background: Virtual reality-based educational software is a valuable tool and strategy that can effectively address challenges in nursing education.

Objectives: This scoping review aimed to determine the impact of virtual reality on the clinical skills and performance of undergraduate nursing students. The review was conducted in 2022.

Methods: Articles were retrieved by searching relevant keywords in databases such as PubMed, Scopus, Web of Science, Springer, ERIC, PsycINFO, CINAHL, EMBASE, SID, and Magiran. After applying the inclusion criteria and quality indicators, seven papers were selected from an initial pool of 158. Data extraction was conducted using a standardized form, and the collected data were then summarized and reported.

Results: Four randomized controlled trials and two quasi-experimental studies indicated that using virtual reality as a supplementary tool can improve nursing students' performance in various clinical skills. These skills included tracheostomy and skin care, preoperative fire safety, intravenous catheter insertion, Foley catheter care, documentation during disasters, care for pregnant patients, and other related competencies.

Conclusion: The authors recommend further research on virtual reality-based techniques grounded in learning theories and used as a supplement to face-to-face training. Such approaches could ultimately enhance patient safety.

Keywords: Virtual Reality; Undergraduate Nursing Students; Clinical Skills; Performance

Background

The use of computers to educate nursing students is at the forefront of contemporary educational approaches. Nursing professors constantly face challenges, including maintaining patient safety and boosting students' self-confidence. Addressing these challenges is essential for enhancing the competence and clinical performance of nursing students (1). Nurse educators also consistently encounter difficulties in bridging the gap between theoretical knowledge and clinical practice (2, 3). Evidence-based practice could help reduce this gap. Furthermore, rapid changes in science and technology, the rising prevalence of chronic diseases, the growing preference for home care, shorter hospital stays, and the unique characteristics of third-millennium students are among the factors complicating nursing education (4, 5). On the other hand, the global nursing shortage and the pressure to enroll more students have created significant challenges for nursing schools, such as insufficient manpower, limited educational space and time, and inadequate resources. Many nursing professionals believe substantial changes are needed in nursing education (6).

Virtual Reality Simulation (VRS) is currently one of the most important approaches used in nursing education (7). VRS is a computer-aided training program that generates images and objects in a three-dimensional environment, creating a sense of immersion for the user. Through this simulation, users can immerse themselves in a virtual world where they interact with objects and people as if they were in reality (8). The learner interacts realistically within a computer-based, three-dimensional setting. While traditionally used for gaming and entertainment, this technology is now rapidly being adopted in aviation, military, and medical education (9). Two main types of virtual reality

have been introduced. The first is desktop-based virtual reality, accessed through a computer screen, keyboard, mouse, touchscreen, or joystick. The second type involves immersive virtual tours, which allow users to explore, shop, and visit locations in a virtual world. This form of virtual reality can be displayed on large screens or through stereoscopic units, and its use in training is increasing (10, 11).

The use of simulation- and virtual reality-based educational software as a valuable strategy and tool is effective in addressing challenges in nursing education. Simulation-based training software creates a virtual clinical environment that allows nursing students to interact with virtual patients. This provides opportunities to practice nursing care while enhancing psychomotor skills and evidence-based decision-making (12). When designing virtual reality environments, pedagogical approaches based on cognitivism, constructivism, and behaviorism must be considered (13). By utilizing virtual reality techniques, students can improve their active participation and problem-solving skills. In this context, applying the principles of constructivist theory, such as providing prompt feedback, is crucial (14). The design of virtual reality environments often integrates educational principles like collaborative learning, active learning, teacher-student interaction, feedback, and task timing. These models also account for student characteristics (e.g., age, prior knowledge) and curriculum, as well as design features such as learning objectives, realism, guidelines, evaluation, and instructor review of simulation scenarios. Therefore, virtual reality can play a significant role in promoting students' self-confidence (15, 16). Using virtual reality also enhances students' critical thinking skills. This technique allows students to learn important procedures without risking harm to actual patients. They can train in procedures such as intravenous line insertion, wound care, and phlebotomy. Additionally, they can use three-dimensional anatomical models for patient assessment and follow-up (17). This educational approach enables students to practice skills repeatedly, thereby reinforcing learning (18). Furthermore, VRS allows nurse educators to create realistic clinical environments for students in a safe setting, enabling them to learn care procedures while ensuring patient safety (19). In today's digital world, VRS not only helps students master their curriculum but also enhances their digital literacy and computer skills (20). In a study by Jason and Forsyth, Virtual Reality Simulation (VRS) was reported to reduce learners' anxiety, improve the accuracy of client care, and enhance clinical competence. It also helped update trainers' knowledge and reduce their anxiety. This review highlights how nursing schools employ this innovative technology and suggests its implementation can help bridge the gap between theory and clinical practice, ultimately improving nursing students' learning and promoting safe patient care (21). Other advantages of this approach include its flexibility, allowing education to occur anytime and anywhere (22). Perhaps one of the greatest advantages of VRS is the ability to manipulate the learning environment through features like magnification, highlighting, and tagging. Additional key benefits include interactive tests and quizzes, opportunities for peer learning, and the absence of geographical limitations in disseminating information (6). The feasibility of simultaneous learning for multiple learners worldwide in a virtual hospital, combined with the exchange of information and experiences without time or space constraints, provides unique learning opportunities for medical and nursing students (23).

Objectives

Recognizing the importance of effective teaching methods in nursing and the positive impact of simulation-based education, this scoping review aims to evaluate the effect of virtual reality (VR) on the clinical skills and performance of undergraduate nursing students. By conducting a comprehensive review of the literature and explicitly defining the components of the PICO framework, this study seeks to formulate and address the central research question. Specifically, we aim to determine how VR-based educational interventions (P: nursing students; I: virtual reality; C: traditional teaching methods such as lectures, demonstrations, or simulation without VR; O: clinical performance) influence the development of nursing students' clinical competencies.

Accordingly, our primary research question is:

"Among nursing students, how does virtual reality–based education, compared with conventional teaching approaches, affect their clinical performance across various nursing procedures and skills?"

Methods

Design: No single research paradigm was applied in this scoping review. The researchers employed both positivist approaches to describe and explain the assessment methods used, and constructivist

approaches to clarify the theoretical frameworks that influenced the choice of assessments (24).

Search strategy: This scoping review was conducted without time restrictions, and the literature search was performed up to the end of 2024. International databases (ERIC, PsycINFO, CINAHL, EMBASE, PubMed, ScienceDirect, Scopus, Web of Science) and national Iranian databases (SID, Magiran) were searched. An example of the search strategy used in some databases is shown in Table 1. Keywords included "smart glass," "virtual clinical education," "nursing student," "performance," "skill," "training," "education," "clinical education," "nurse*," "bachelor of science," "undergraduate," "undergraduate nursing student," and "ability." Boolean operators (AND, OR) were applied. All search results, including titles and abstracts, were imported into EndNote 7 software. Articles in Persian and English that focused on populations other than nursing students were removed.

Table 1. The search strategy in some databases

Database	Search Strategy
PubMed	((((((("virtual reality*"[Title] AND "performance*"[Title]) OR "practice*"[Title] OR "skill*"[Title] OR "enhance"[Title]) AND "nurs*"[Title/Abstract]) OR "Virtual Clinical Education"[Title/Abstract] OR "Google glass"[Title/Abstract]) AND "student"[Title]) OR "learner"[Title] OR "Outcome learning"[Title])
Scopus	(TITLE("Virtual*" OR "Virtual Reality*" OR "VR") AND (TITLE("Performance*" OR "Learner" OR "Outcome" OR "Outcome learning*")) AND TITLE("nurs*"))
Web of Science	(TI=("performance*" OR "practice*" OR "Outcome") AND TI=("VR" OR "Virtual reality" OR "Virtual reality simulation") AND TI=("Learner" OR "Outcome learning") AND TI=("Nursing student"))
SpringerLink	("virtual reality" OR "virtual clinical education" OR "augmented reality") AND ("nursing student" OR "nursing education") AND ("performance" OR "clinical skill" OR "competence")
ERIC	(("virtual reality" OR "online simulation" OR "virtual clinical training") AND ("nursing student" OR "undergraduate nursing") AND ("performance" OR "learning outcomes" OR "skill development"))
PsycINFO	(("virtual reality" OR "simulation training") AND ("nursing student" OR "healthcare education") AND ("performance" OR "clinical competence" OR "skill acquisition"))
CINAHL	(("virtual reality" OR "virtual simulation" OR "smart glass") AND ("nursing student" OR "undergraduate nursing") AND ("clinical skill" OR "performance" OR "competency"))
EMBASE	('virtual reality'/exp OR 'augmented reality'/exp) AND ('nursing student'/exp OR 'nursing education') AND ('performance'/exp OR 'clinical skill'/exp OR 'competence'/exp)
SID	("توانمندی" OR "مهارت بالینی" OR "عملکرد") AND ("دانشجوی پرستاری") AND ("آموزش بالینی مجازی" OR "واقعیت مجازی")
Magiran	("مهارت بالینی") AND ("دانشجوی پرستاری") AND ("شبیه‌سازی بالینی" OR "آموزش مجازی" OR "واقعیت مجازی" OR "آموزش بالینی" OR "عملکرد")

Inclusion and Exclusion Criteria: Original Persian and English studies published in peer-reviewed journals with full-text availability were included. Letters, gray literature, review articles, commentaries, editorials, and conference proceedings were excluded.

This review evaluated the performance of nursing students without restrictions on the type of skill or clinical specialty.

Search Outcome: Initially, 158 articles were retrieved. After removing duplicates, 124 studies remained for title and abstract screening. If there was ambiguity, the full text was downloaded and evaluated by two authors. Studies that resolved the ambiguity were included, while others were excluded. Ultimately, 19 studies met the inclusion criteria and were assessed using 11 quality indicators developed by Buckley et al. (2009), which evaluated study design, methods, analysis, results, and conclusions. Studies scoring 7 or higher were considered high quality (Table 2). All 19 studies were independently scored by two authors, and discrepancies were resolved through discussion. Thirteen studies scoring below 7 were excluded due to reasons such as lack of ethical considerations, incomplete data on sample attrition, mismatch between objectives and results, or methodological issues (Figure 1).

Data extraction: All authors were involved in extracting and classifying information. The extracted data included author(s)/year of publication, country of origin, study aim, design, sample and study population, data collection methods, and methods of analysis (Table 3).

Table 2. Quality indicators for included studies (42)

Quality Indicator	Detail
Research Question	Is the research question or hypothesis clearly stated?
Study Subjects	Is the subject group appropriate for the study (considering number, characteristics, selection process, and homogeneity)?
Data Collection Methods	Are the methods used (qualitative or quantitative) reliable and valid for the research question and context?
Completeness of Data	Is subject attrition reported? Is the attrition rate less than 50%? For questionnaire-based studies, is the response rate adequate?
Control for Confounding	Have potential confounding factors or variables been controlled, removed, or accounted for where possible?
Analysis of Results	Are the statistical or other analytical methods used appropriate for the study?
Conclusions	Do the data clearly justify the conclusions drawn?
Reproducibility	Is the study described in sufficient detail to be reproduced by other researchers?
Prospective Design	Is the study prospective (looking forward in time) rather than retrospective (looking backward)?
Ethical Issues	Were all relevant ethical issues appropriately addressed?
Triangulation	Were the results supported by data from more than one source or method?

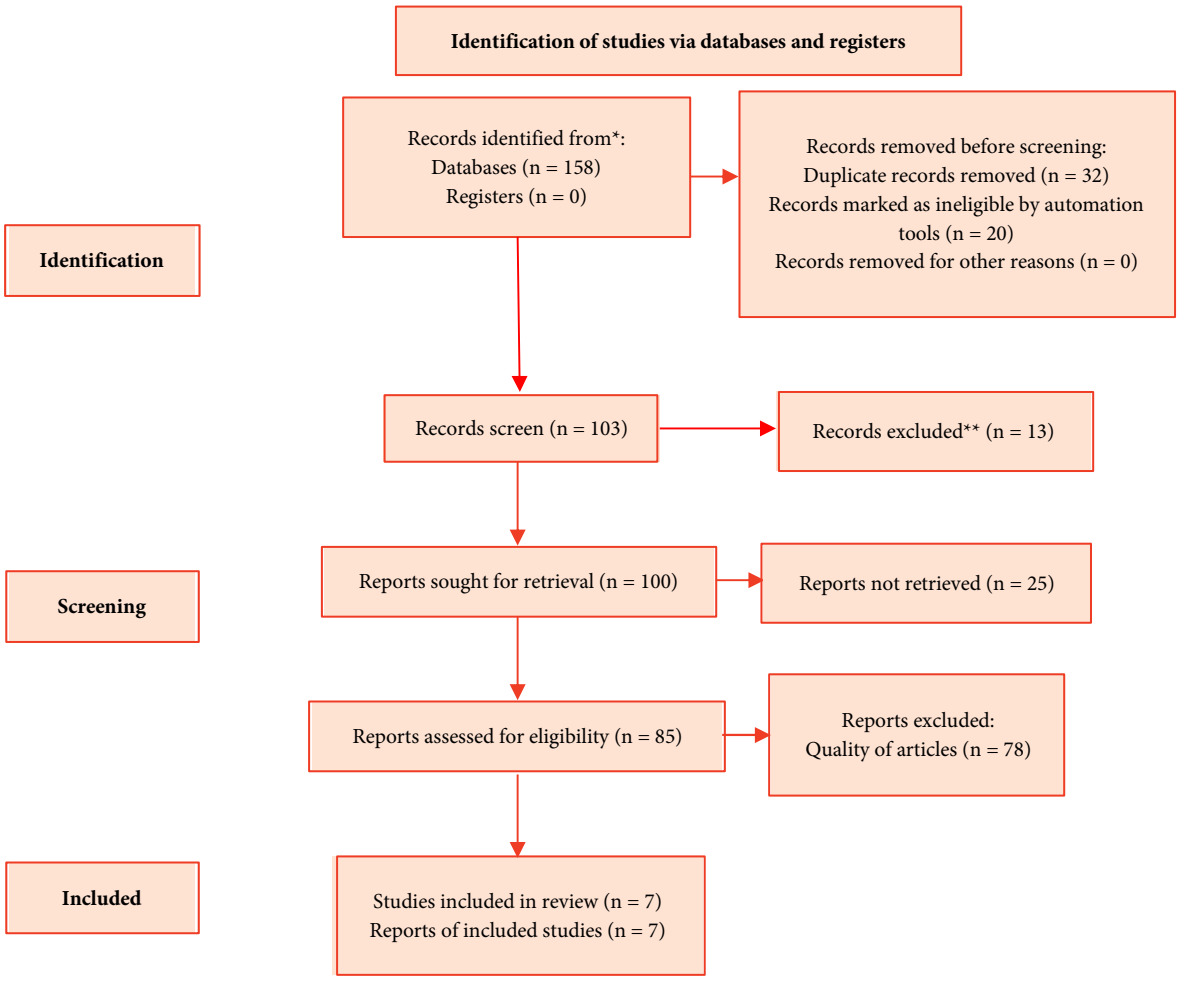

Figure 1. The paper selection process

Table 3. Summary of included nursing studies for the effectiveness of Virtual Reality on Skill and Performance

Author /year/ country	Aim	Design	Comparison (Control) group	Sample and study population	Data collection	Method of analysis
Bayram and Caliskan (2019)/Turkey	Determining the effect of a game-based virtual reality phone application on tracheostomy care education for nursing students.	Single-blind randomized controlled trial	Theoretical class and demonstration on the mannequin	N=86 First-year nursing students	Informative features form, A tracheostomy care knowledge test and skill checklists, and a performance assessment form OSCE	Descriptive Nonparametric tests
Jung et al./ (2012)/Korea	Confirmed the educational effectiveness of practical exercises (PE) using intravenous (IV) simulators incorporating virtual reality (VR)/haptics (based on the sense of touch) device technologies.	A randomized controlled trial	Conventional arm model	N :114 First- year nursing students	Personal information, basic knowledge measurement, trait and state anxiety measurement, training materials, and effectiveness of training.	Descriptive Nonparametric tests (Mann–Whitney U test), Paired t-test, one-way ANOVA
Smith et al./ (2018)/USA	To assess two levels of immersive virtual reality simulation (VRS) to teach the skill of decontamination.	Quasi experimental design/Focus group	Written instructions	N=197 Senior baccalaureate nursing students	Decontamination Checklist/ Interview and focus group	Descriptive/ Repeated measures/ Qualitative analysis techniques
Smith and Hamilton/ (2015)/USA	To evaluate the effectiveness of VR simulation as a teaching strategy for preparation of students for successful performance and validation of Foley catheter insertion by generic associate degree nursing (ADN) students.	Randomized Control Trial	Instructions in a classroom setting	N=20 Nursing student with Fundamental Course	Demographic Questionnaire Log Sheets Skills Evaluation Tool Visual Analog Perceived Preparedness Scale	Descriptive statistics Independent-samples t- test Pearson correlations
Ismailogˇlu and Zyback (2014)/Turkey	Compare the effects of using a VIS with a plastic arm model for teaching IV catheter insertion skills to nursing students.	A Randomized controlled quasi-experimental study	Plastic arm model	N= 65 2nd. -year students	Personal Information Form Intravenous Catheterization Knowledge Assessment FormIntravenous Catheterization Skill Checklist Visual Analog Scale The Fear Symptoms Scale	Data were analyzed using IBM SPSS version 18
Rossler et al./ (2018)/USA(Texas)	The effectiveness of the Virtual Electrosurgery Skill Trainer (VEST) on OR fire safety skills among prelicensure nursing students	An experimental pretest-posttest (Pilot study)	Traditional programmatic education	N=20 Enrolled in the perioperative nursing elective course	Perioperative Performance Evaluation Tool 10-item researcher-made tool to test knowledge level	Descriptive Wilcoxon test
Chang et al./ (2022)/Taiwan	An exploratory study using social learning theory embedded in SVVR for childbirth education training is presented; moreover, the learning performances of nursing students who participated in SVVR classroom learning and those who learned with the traditional approach were compared	A quesi experimental	Traditional programmatic education	N=30 Care for pregnant women	Spherical Video-based Virtual Reality (SVVR)	ata were analyzed using IBM SPSS Statistics version 18 Descriptive Wilcoxon test

Results

Initially, 158 articles were identified from the following databases: PubMed (43), Scopus (20), Web of Science (44), PsycINFO (20), ERIC (4), EMBASE (3), and CINAHL (12).

Study Characteristics: This scoping review included Seven studies examining the impact of virtual reality on the skills and performance of nursing students. No studies were conducted in Iran.

The studies originated from Turkey (2), the United States (3), Taiwan (1), and Korea (1). Among these Seven studies, four were randomized controlled trials, and two were quasi-experimental.

Sample sizes ranged from 20 to 197 participants, totaling 550 individuals. All studies were single-blind and conducted between 2011 and 2022. They focused on topics such as tracheostomy care, fire safety, intravenous catheter insertion, IV injection, disaster documentation, care for pregnant women, and Foley catheter care.

Virtual reality simulator specifications

- In the study by Bayram & Caliskan (2019), a video demonstrating tracheostomy care based on a researcher-developed checklist was created. An offline, game-based virtual reality application for Android phones was then developed using CS6 and Adobe Flash CC. The game featured a nurse character guiding the student through suctioning and caring for the patient character Mr. Melek's tracheostomy in six steps over ten minutes. Upon completion, students could save and send their progress to the researchers (25).
- In the study by Rössler et al. (2019), the virtual reality simulation was designed in four sections: (a) learning objectives, (b) a replicated operating room environment, (c) a human patient simulator portraying a surgical patient, and (d) a simulated fire source. Participants were introduced step-by-step to the role of an operating room nurse and had to complete each stage correctly to proceed (26).
- The Virtual Intravenous Simulator (VIS), used by Ismailoglu and Zaybak (2018), is a VR-based simulator designed to enhance psychomotor skills for intravenous catheter insertion. It incorporates a haptic device simulating a patient's arm with a valve for needle insertion. A sensor system detects movements and translates them into a 3D computer environment. The simulator offers various clinical scenarios with different vascular structures (27).
- The simulator in the study by Jung et al. also used a haptic device to provide tactile resistance during vein puncture within a 3D image viewed through polarized glasses. The skin and vein pathway were displayed on a monitor, allowing learners to experience needle insertion. It demonstrated anatomical features, complications, injection techniques, and intravenous therapy (28).
- In the study by Smith et al. (2018), a virtual reality simulator introduced students to the use of Personal Protective Equipment (PPE) in the emergency department via a ten-minute scenario developed using the Unity 3D game engine. Models and characters were designed in Autodesk Maya. Students could explore the virtual emergency unit using a VR headset and select equipment by pressing a button on a manual controller (29).
- In the study by Smith and Hamilton, a virtual reality simulator was designed to train students in Foley catheter insertion. Learners performed urinary catheterization step-by-step on screen. If an error occurred, an alert sound prompted them to return to and correct the step. The simulator was operated using a mouse (30).
- The study by Chang et al. (2022) aimed to enhance nursing students' preparedness to care for pregnant women and support safe childbirth processes using virtual reality (31).

Performance outcomes

- Bayram et al. (2019) reported statistically significant differences favoring the VRS group in scores for tracheostomy tube suctioning ($p = 0.017$) and peristomal skin care ($p = 0.003$). They recommended VRS for teaching these skills but suggested future studies include longer follow-up periods (25).
- Rössler et al. (2019) found a statistically significant difference in students' performance skills related to an emergency fire scenario and the PASS technique (Pull, Aim, Squeeze, Sweep) between the intervention and control groups ($p = 0.001$). The authors recommended VRS for beginner students in both academic and clinical courses. They noted limitations including optional participation and unaccounted-for prior VR experience (26).
- Ismailoglu and Zaybak (2018) reported a statistically significant difference in mean psychomotor skill scores (experimental: 45.18 vs. control: 20.44, $p < 0.001$) on the simulator. However, no significant

difference was found in subsequent clinical psychomotor skill scores (p = 0.841). They recommended VIS for teaching IV insertion but suggested future research assess skills in real clinical settings (27).

- Jung et al. compared three groups: Conventional Arm Model, VR/Haptic IV Simulator, and IV Arm + IV Simulator. While no significant difference was found in overall performance scores, a statistically significant difference was observed in procedure duration (p = 0.007), with the IV Arm + IV Simulator group being fastest. The authors recommended combining VR with hands-on skill lab training. Limitations included insufficient training time and unaddressed cultural heterogeneity (28).
- Smith et al. (2018) did not find a statistically significant difference in overall performance between groups in a disaster documentation scenario. However, women in the VR group completed documentation faster than men (p = 0.007). Performance scores declined in all groups at six months post-intervention. The authors recommended VR for teaching disaster preparedness, noting limited generalizability (29).
- Smith and Hamilton (2015) found no statistically significant difference between the VR and control groups for Foley catheter care. However, mean scores showed a positive trend for the VR group, and the mean procedure time was shorter in the intervention group (125 ± 66.08 seconds vs. 182.50 ± 71.92 seconds). The authors suggested VR could be a supplementary learning tool (30).
- Chang et al. (2022) reported that students learning through Spherical Video-based Virtual Reality (SVVR) demonstrated higher learning motivation and satisfaction compared to traditional instruction, highlighting its potential for childbirth education (31).

Discussion

This review examined the effect of virtual reality simulation (VRS) on the skills and performance of nursing students. Some of the included studies confirmed the positive impact of VRS on performance, while others, despite not reporting statistically significant results, recommended its use due to advantages such as reduced procedure time, opportunities for repeated practice, safe training for invasive procedures, maintained patient safety, and increased student satisfaction.

Supporting findings come from other fields. Kundhal and Grantcharov (2009) found medical students trained with VRS for laparoscopic procedures completed tasks significantly faster ($p < 0.05$) (32). Janse et al. (2013) noted benefits of VRS for medical students inexperienced in hysterectomy (33). Konge et al. (2013) observed significant improvement in respiratory physicians' ability to diagnose lymph nodes using VRS, recommending its use before clinical practice (34, 35). Conversely, Andersen et al. (2015) found no significant difference in performance for mastoidectomy simulation (p = 0.22) (36). Jimenez et al. (2018) found a VR game more effective than traditional education for teaching cancer patients about radiation therapy, attributing success to its engaging nature (reference implied but not listed in text).

In anatomy education, Gorski et al. (2016) reported that a 3D VR application (KOMVR) improved engineering students' understanding of human anatomy and reduced wait times for learning resources (37). Ekstrand et al. (2018) found medical students who watched a 3D neuroanatomy video achieved higher knowledge scores (38). Soltun et al. (2019) demonstrated that 360-degree VR significantly increased knowledge and motivation in medical students (39). Gopal et al. (2018) found a VR learning system (VR4MAX) significantly improved medical students' bronchoscopy skills and knowledge (40). In contrast, Blumstein et al. (2020) found no significant knowledge difference between VR and standard teaching for tibial surgery techniques, calling for further research with larger samples and validated measures (41).

Limitations: Although the search strategy was extensive, some studies may have been missed. The full texts of two articles were unavailable; requests sent to the authors received no response, leading to their exclusion. This review was limited to English and Persian publications, potentially omitting relevant studies in other languages.

Conclusion

The use of virtual reality (VR) technology in nursing education is becoming increasingly prominent. Undergraduate students, particularly those from the millennial generation, often show less inclination toward traditional classroom attendance and rigid schedules. Consequently, virtual learning can serve as a valuable educational tool for this population. VR

technology is particularly beneficial for teaching clinical skills and enhancing performance. Given the practice- and repetition-oriented nature of nursing, hands-on clinical experience remains essential alongside theoretical knowledge. Compared to traditional methods, VR offers a promising strategy to mitigate risks in nursing education. By integrating VR as a supplement to hands-on training in skill labs and clinical settings, educators can enhance student learning while maintaining patient safety and effectively preparing competent professional nurses.

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Conflict of interests: There is no conflict of interest.

Ethical approval: This systematic review was conducted in accordance with the ethical principles of secondary research and was approved by the Research Ethics Committee of Tehran University of Medical Sciences (Ethics Code: IR.TUMS.MEDICINE.REC.1399.159). As a review of published literature, this study adhered to the principles of academic integrity through proper citation and accurate reporting of primary findings. The review process followed PRISMA guidelines to ensure transparency and reproducibility, and two independent reviewers screened the studies and assessed their quality to minimize bias.

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