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Effect of a technological innovation model applied to the educational process of procedures in the training of undergraduate nursing students: A systematic review

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ADMINISTRATIVE INFORMATION

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Review Stage at time of this submission - Risk of bias assessment.

Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 2 June 2026 and was last updated on 2 June 2026.

INTRODUCTION

Review question / Objective To analyze the available scientific evidence on the effect of technological innovation (VR or IVR) on the acquisition of procedural competencies in undergraduate nursing students through a systematic review. The research question was formulated according to the PICO framework (Population, Intervention, Comparison, and Outcome), where: P, Undergraduate nursing students; I, Technological innovation applied to the educational process (virtual reality and AI) in procedures; C, Traditional teaching, conventional learning methods, or absence of technology; O, Improvement parameters in training: acquisition of clinical competencies, patient safety, reduction of errors, knowledge retention, and/or student satisfaction.

Rationale The training of undergraduate nursing students requires not only the acquisition of theoretical knowledge but also the development of procedural competencies that ensure safe, effective, and evidence-based clinical performance. In this context, the incorporation of technological innovation into the educational process, particularly virtual reality (VR), has emerged as a high-potential strategy to strengthen procedural learning, facilitate repeated practice in simulated environments, and promote an immersive and meaningful learning experience. However, despite the growing interest in these tools, the scientific evidence regarding their actual effect on procedural training remains dispersed, heterogeneous, and in some cases, inconclusive. Conducting a systematic review on the effect of a technological innovation model applied to the educational process in nursing procedures is relevant, as it allows for a rigorous synthesis of the available evidence and determines whether VR consistently contributes to improving relevant outcomes in professional training. These outcomes highlight the acquisition of clinical competencies, error reduction during the execution of procedures, knowledge retention, patient safety, and student

satisfaction. These designs are particularly important in nursing, since the quality of training directly impacts the care provided to patients and the student's safe transition to the real clinical environment. Furthermore, this review is relevant because the existing literature often presents significant variations regarding the type of technological intervention used, the design of educational programs, duration of exposure, evaluated procedures, and outcome measurement instruments. Likewise, the comparators used are not always equivalent: some studies use traditional teaching, others conventional learning with practical demonstrations, and others a total absence of technology. This methodological diversity hinders the direct comparison of findings and limits the possibility of drawing solid conclusions about the effectiveness of VR. Another fundamental reason for developing this review is that the field of technological innovation in health education is evolving rapidly; consequently, even when previous systematic reviews on the use of virtual reality in areas such as health sciences or nursing exist, they are not focused on undergraduate nursing students or specific clinical procedures. In this sense, this review is justified by seeking to more accurately delimit the population, intervention, comparator, and outcomes of interest, as well as incorporating more recent studies. This systematic review will help guide the decision-making of educators, training institutions, and curriculum developers regarding the use of virtual reality as a pedagogical resource. If the evidence shows consistent benefits, its integration into curricula could be supported as a complement or partial substitute for traditional strategies. If, conversely, the results are limited or inconsistent, the review will identify areas requiring further research prior to widespread implementation, thereby favoring the generation of relevant and applicable knowledge. In summary, this systematic review is justified by the need to critically analyze the best available evidence on the effect of virtual reality-based technological innovation on the procedural training of undergraduate nursing students. Its completion will clarify the current state of knowledge, identify evidence gaps, and offer solid foundations for future research, pedagogical decisions, and educational policies in nursing training.

Condition being studied The core issue of this topic lies in the acquisition of clinical procedural competencies and the subsequent exposure of patients to adverse events during the training of undergraduate nursing students. The teaching of technical procedures through traditional methods often faces limitations such as restricted access to real clinical scenarios, variability in faculty supervision, and the ethical risk of "practicing" directly on the patient, which can lead to poor skill retention and an increase in medical errors. Consequently, the central factor of interest is the impact of the Virtual Reality (VR)-based technological innovation model as a pedagogical intervention. The aim is to analyze how this technology addresses the lack of technical dexterity and clinical safety, analyzing specific events such as precision in procedural execution, the decrease in the technical error curve, and the strengthening of student confidence prior to their interaction with the real hospital environment.

METHODS

Search strategy A literature search was conducted up to April 15, 2026, following the PRISMA-2020 guidelines in databases such as PubMed, Web of Science, Scopus, Scielo, and LILACS, using the following search strategy: ((((((((((Virtual Reality[MeSH Terms]) OR (virtual reality[Title/Abstract])) AND (Students, Nursing[MeSH Terms])) OR (nursing students[Title/Abstract])) AND (Clinical Competence[MeSH Terms])) OR (procedural skills[Title/Abstract])) OR (clinical skills[Title/Abstract])) AND (Education, Nursing[MeSH Terms])) OR (nursing education[Title/Abstract])) AND (simulation[Title/Abstract])) AND (training[Title/Abstract]). Similarly, grey literature was consulted to identify unpublished studies with potential use within the systematic review. The retrieved manuscripts were independently evaluated by a pair of reviewers, and once selected using the eligibility criteria, the full text was obtained.

Participant or population Undergraduate nursing students of any gender, without age or ethnic restrictions. The justification lies in the fact that the undergraduate level represents the training stage where basic clinical competencies are acquired and the first procedural learning curve is established, differentiating itself from technical or postgraduate training by its academic scope and professional responsibility. Studies whose learning environment is academic (simulation laboratories, classrooms) are included. As ineligible studies, those focusing on professional nurses, postgraduate or specialty students, nursing technicians, or any other healthcare team professional not pursuing an undergraduate degree are strictly excluded, in order to avoid biases derived from previous clinical experience or differences in graduate profiles.

Intervention The intervention of interest consists of the implementation of a Virtual Reality (VR)-based technological innovation model, integrated into the teaching-learning process of clinical procedures. Studies using VR systems in their various modalities will be included: Immersive VR (through the use of virtual reality glasses or headsets —HMD— that isolate the user from the physical environment) and Semi-immersive VR (through projection systems or large-format screens with spatial interaction). The intervention must be specifically designed for training technical procedural competencies inherent to nursing (e.g., catheterization, medication administration, wound care, among others). Variations in the intervention will be accepted, including the use of VR as a sole learning tool or as a complement to traditional clinical simulation (hybrid interventions). However, to ensure the review's specificity, interventions based on 2D games without a three-dimensional virtual environment, or the use of telemedicine platforms and mobile applications that do not simulate an immersive procedural environment, will be excluded. Additionally, supplementary interventions incorporating haptic feedback or virtual tutoring within the same VR ecosystem will be considered acceptable.

Comparator The comparator of interest in this systematic review corresponds to traditional or conventional teaching methods used in the training of clinical procedures for undergraduate nursing students. These include, but are not limited to, theoretical lectures, practical demonstrations by the instructor, supervised laboratory practice with low- or medium-fidelity mannequins, independent study, and learning based on texts or non-interactive audiovisual materials. Likewise, studies comparing the intervention with an absence of immersive technology or with standard educational interventions without the use of virtual reality will be considered. In cases where active comparators are included (e.g., high-fidelity traditional clinical simulation), these must be clearly described to allow for their differentiation from VR. Interventions incorporating similar immersive technologies (such as VR in another modality) or those that do not allow the specific effect of the intervention of interest to be isolated will be excluded as comparators. This is to ensure a valid comparison that allows evaluating the added value of virtual reality versus conventional educational strategies.

Study designs to be included This systematic review will preferentially include Randomized Controlled Trials (RCTs), as they are the most robust design to determine the efficacy of an educational intervention and minimize selection biases. However, quasi-experimental designs will also be included, such as non-randomized controlled studies, pre-post studies with a control group, and cohort studies. Studies reporting quantitative measurements of learning outcomes (competencies, errors, time, etc.) will be considered. Single case studies, case series, opinion articles, editorials and descriptive cross-sectional studies.

Eligibility criteria Studies will be included if they evaluate undergraduate nursing students (P), implement virtual reality-based interventions for learning clinical procedures (I), compared with traditional teaching methods or absence of immersive technology (C), and report outcomes related to the acquisition of procedural competencies, patient safety, error reduction, knowledge retention, or student satisfaction (O), using experimental or quasi-experimental designs (S). Additionally, studies published in peer-reviewed scientific journals, without country restriction, and in English or Spanish language will be included. Studies with ineligible populations (credentialed professionals, students from other disciplines without independent analysis), interventions not corresponding to virtual reality, absence of a comparator group, or those not reporting outcomes related to the endpoints of interest will be excluded. There will be no publication year limitation to capture the evolution of evidence in this field. All criteria will be defined a priori and maintained without modifications during the review's development; if adjustments are required after the protocol's registration, these will be duly justified and documented, accompanied by sensitivity analyses to evaluate their impact on the results.

Information sources An exhaustive search was conducted in the following electronic databases: PubMed, Web of Science, Scopus, Scielo, and LILACS. Additionally, grey literature was searched in TESIUNAM and Google Scholar.

Main outcome(s) The primary outcome will be the acquisition of procedural competencies, measured through validated technical performance scales (such as Objective Structured Assessment of Technical Skills [OSATS]-type rubrics or critical step checklists), evaluated immediately after the intervention and/or at the end of the academic cycle. As secondary outcomes, the following will be evaluated: a) patient safety and error reduction, quantified by the frequency of errors committed during procedural execution; b) knowledge and skills retention, measured in a medium-term follow-up (minimum 4 weeks after the intervention); and c)

student satisfaction and perceived self-efficacy, evaluated using Likert-type scales.

Additional outcome(s) Outcomes providing relevant information to understand the overall effect of the virtual reality and AI-based intervention will be included. These will consider: a) the execution time of procedures; b) the perceived cognitive load, evaluated through validated instruments, to explore the impact of the virtual environment on information processing; and c) technology acceptance and usability.

Data management To ensure process transparency and reproducibility, the study selection review will be carried out independently by two reviewers, with the involvement of a third reviewer if necessary. The screening process will be managed using specialized software for systematic reviews where all inclusion and exclusion decisions will be recorded. Data extraction will be performed using a previously piloted standardized form, which will include variables related to the PICO elements, methodological characteristics, and outcomes of interest. Tools such as Microsoft Excel will be used for data management and organization, and if quantitative synthesis is performed, RevMan software will be utilized.

Quality assessment / Risk of bias analysis For randomized clinical trials, the RoB 2 (Cochrane Risk of Bias) tool will be used, whereas the ROBINS-I tool will be used for non-randomized studies, allowing the assessment of domains such as selection, performance, detection, attrition, and selective reporting bias. Results will be presented in summary of findings tables, allowing a transparent and structured interpretation of the strength of the available evidence.

Strategy of data synthesis Comprehensive and differentiated analysis of changes regarding the use of applied technology in procedures. A differential and comprehensive analysis will be carried out regarding the outcome of competency acquisition and perception; concerning the analysis criteria, results will be classified according to variable type. Data synthesis will be presented through a table centralizing the data (Author, year, country, study design, population and characteristics, type of intervention (VR group) vs. comparator, measurement instrument, main outcomes).

Subgroup analysis No.

Sensitivity analysis A sensitivity analysis will be conducted to evaluate the robustness of the findings and determine whether certain methodological decisions significantly influence the overall results of the review. This analysis will focus on methodological quality, comparing results by including and excluding studies with a high risk of bias and non-validated instruments.

Language restriction Studies published inEnglish, Portuguese, and Spanish.

Country(ies) involved Mexico.

Keywords Virtual reality; Clinical competencies; Digital simulation; Nursing education; Nursing students.

Dissemination plans The selection of a journal for the publication of the systematic review results is proposed.

Contributions of each author

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