

# The Effectiveness of Virtual Simulation in Knowledge of Nurses: A Protocol for Systematic Review and Meta-Analysis of Randomized Controlled Trials

Jacqueline Maria Dias<sup>1</sup>, Aram Halimi<sup>2</sup>, Sahar Sotoodeh Ghorbani<sup>2</sup>, Alizera Mosavi Jarrahi<sup>3</sup>,  
Amina Al-Marzouqi<sup>4</sup>

## Abstract

**Background:** Nursing education is evolving with technological advancements, including the adoption of virtual simulation. This protocol outlines a systematic review and meta-analysis aimed at evaluating the effectiveness of virtual simulation in improving nurses' knowledge.

**Methods:** The study adheres to PRISMA guidelines and is registered in PROSPERO (registration number CRD42022352907). Eligible studies encompass randomized controlled trials (RCTs) that examine virtual simulation's impact on registered nurses, student nurses, or nursing professionals. The intervention involves various virtual simulation tools (virtual reality, augmented reality, serious games) compared against traditional methods or control groups. The primary outcome is improved nursing knowledge, measured through validated assessment tools. Methodological quality will be assessed using the Cochrane Risk of Bias tool.

**Results:** Electronic databases (PubMed, Scopus, Web of Science, PsycINFO) will be systematically searched for eligible studies. The search strategy combines controlled vocabulary terms and keywords to ensure comprehensive retrieval. Two reviewers will independently screen titles, abstracts, and full texts. Data extraction will be standardized to collect study details, participant characteristics, intervention specifics, outcome measures, and findings related to knowledge enhancement.

**Analysis:** Quantitative synthesis (meta-analysis) will be conducted if sufficient homogeneity exists among the included studies. Heterogeneity will be assessed using statistical tests, with subgroup and sensitivity analyses for further exploration. The GRADE approach will assess evidence quality and recommendation strength, considering bias risk, heterogeneity, indirectness, precision, and publication bias.

**Keywords:** Virtual simulation, Virtual reality, Augmented reality, Three-dimensional simulation, Nursing Education, Nursing training, Nursing curriculum, Knowledge acquisition, Learning outcomes, Educational Effectiveness

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## Correspondence to:

Jacqueline Maria Dias, RN,  
Ph.D.  
Department of Nursing,  
College of Health Sciences,  
University of Sharjah, Shar-  
jah, UAE.

**Email:** [jdias@sharjah.ac.ae](mailto:jdias@sharjah.ac.ae)

## Affiliations:

<sup>1</sup> Department of Nursing,  
College of Health Sciences,  
University of Sharjah, Shar-  
jah, UAE

<sup>2</sup> Department of Epidemiol-  
ogy, School of Public Health  
and Safety, Shahid Beheshti  
University of Medical Scienc-  
es, Tehran, Iran.

<sup>3</sup> Professor, Cancer Research  
Centre, Shahid Beheshti Uni-  
versity of Medical Sciences,  
Tehran, Iran.

<sup>4</sup> Department of Nursing,  
College of Health Sciences,  
University of Sharjah, Shar-  
jah, UAE

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## 1. Introduction

The realm of nursing education has been undergoing constant transformation to align with the rapid progress in healthcare technology and inventive teaching approaches. Over recent times, virtual simulation has emerged as a state-of-the-art strategy within nursing education, presenting an innovative learning encounter for both aspiring and practicing nurses. With the escalating requirement for exceptionally proficient and well-informed nurses, investigating the influence of virtual simulation on their knowledge attainment assumes paramount significance (1-3).

Nurturing skilled and well-prepared healthcare professionals capable of navigating the intricate landscape of modern medical practices is a fundamental role of nursing education. Historically, nursing education has heavily relied on didactic lectures, hands-on training, and clinical placements to impart crucial competencies and knowledge to nursing students. Nevertheless, these conventional methods possess inherent limitations, including the potential hazards tied to real-life patient interactions during training and the inconsistencies in the quality of clinical exposure. In contrast, virtual simulation presents a controlled and secure environment where learners can engage in diverse clinical scenarios without compromising patient welfare. This avenue offers nurses an opportunity to enhance their proficiency in decision-making, hone critical thinking prowess, and refine clinical judgment within a safeguarded context (4-7).

Virtual simulation encompasses a variety of interactive computer-driven instruments, including virtual reality (VR) and augmented reality (AR) systems, three-dimensional (3D) simulations, serious games, and virtual patient scenarios. These resources have the capability to mimic intricate medical scenarios, spanning from fundamental procedures to intricate emergency situations, granting nurses the opportunity for repetitive practice and immediate feedback. This interactive engagement fosters experiential learning, heightening the retention of knowledge and the application of skills. By means of virtual simulation, nurses can delve into a myriad of patient care scenarios, ones that might be limited or unavailable in conventional clinical settings due to factors such as resource constraints, ethical considerations, or apprehensions related to patient safety (8-12).

Furthermore, virtual simulation effectively tackles the issue of diversity in clinical encounters by furnishing uniform learning prospects. This implies that each nursing

student can engage with an identical clinical scenario, fostering uniformity in the educational journey. This standardization holds exceptional value in guaranteeing that all learners are subjected to equivalent learning aims and outcomes, effectively reducing disparities in education. What's more, virtual simulation boasts the flexibility to be tailored to cater to the individual requirements of learners, facilitating their advancement at their personalized speed and the opportunity to revisit intricate scenarios until a state of mastery is attained. This adaptability underscores virtual simulation's capacity to accommodate diverse learning needs and preferences, further augmenting its educational effectiveness (13-16).

Integrating virtual simulation into nursing education aligns seamlessly with modern learning theories that accentuate dynamic involvement, experiential learning, and context-driven cognition. The interaction with authentic virtual patients and clinical scenarios serves as a link between theoretical understanding and practical application, empowering nurses to anchor their knowledge and competencies within real-world contexts. The capacity to explore diverse strategies, learn from errors, and promptly receive feedback forms the foundation of reflective learning, nurturing a profound comprehension of medical concepts and their tangible implications. This holistic approach bridges the gap between theoretical knowledge and practical proficiency, a hallmark of virtual simulation's contribution to contemporary nursing education (17-20).

Although the potential advantages of employing virtual simulation within nursing education show promise, it is crucial to subject its efficacy to meticulous scientific investigation. This systematic review assumes the task of thoroughly appraising the current corpus of literature, with a particular emphasis on randomized controlled trials (RCTs), in order to ascertain the tangible impact of virtual simulation on the enhancement of nurses' knowledge. Through the amalgamation of evidence derived from RCTs, our objective is to furnish an empirically grounded comprehension of virtual simulation's influence on the acquisition of nursing knowledge. This endeavor ultimately serves to enrich educational methodologies and guide policy decisions, based on substantiated insights garnered from the scientific community (21-23).

To encapsulate, the integration of virtual simulation into nursing education embodies a profound shift in how nurses are trained and primed for their roles in the

healthcare realm. This shift carries with it the potential to bridge the divide separating theoretical understanding from practical application, amplify the capacities of critical thinking, and establish standardized learning experiences that hold substantial promise. Through this systematic review, our intent is to illuminate the efficacy of virtual simulation in nurturing nurses' knowledge, thereby contributing to the ongoing discourse that revolves around the trajectory of nursing education and its alignment with the dynamic demands of contemporary healthcare. In the midst of an ever-evolving healthcare landscape, pioneering educational strategies such as virtual simulation are strategically positioned to endow nurses with the skill sets necessary to provide patient care that is secure, streamlined, and ultimately efficacious.

## 2. Methods

This investigation was carried out following the guidelines set forth by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (24). This protocol has been recorded in the International Prospective Register for Systematic Reviews (PROSPERO) under the registration number CRD42022352907.

### 2.1 Eligibility Criteria

To safeguard the pertinence and robustness of the systematic review and meta-analysis, precise eligibility criteria will be formulated to serve as a guiding framework for the selection of studies.

#### Population

This systematic review will encompass studies involving individuals from the nursing domain, comprising registered nurses, student nurses, or nursing professionals at various educational levels.

#### Intervention

The primary focus will be directed towards studies that embrace virtual simulation as an educational intervention. This sphere encompasses a spectrum of virtual simulation tools, including but not limited to virtual reality (VR), augmented reality (AR), serious games, three-dimensional (3D) simulations, and virtual patient cases.

#### Comparator

The purview of this review will include studies that

juxtapose the effectiveness of virtual simulation against traditional educational methodologies, such as didactic lectures and hands-on training. Additionally, studies contrasting virtual simulation with a control group devoid of any intervention will also be considered.

#### Outcome

The principal outcome of interest revolves around gauging the enhancement in nurses' knowledge. This will be evaluated through robust assessment tools, validated measurement instruments, exams, quizzes, or other pertinent evaluations.

#### Study Design

The review will exclusively encompass randomized controlled trials (RCTs). This choice is predicated upon the methodological robustness of RCTs in delineating causal relationships, rendering them particularly suitable for this investigative endeavor.

### 2.2 Information Sources

The research will be underpinned by a systematic and comprehensive search strategy. This strategy will be adeptly designed to unearth pertinent studies from a myriad of sources. Notably, electronic databases such as PubMed, Scopus, Web of Science, and PsycINFO will be probed for relevant articles. Furthermore, in a bid to leave no stone unturned, gray literature repositories and the reference lists of the identified studies will also undergo meticulous manual screening. This approach is aimed at identifying potentially overlooked studies that might not have surfaced in the primary database exploration.

### 2.3 Search Strategy

The crafting of the search strategy will be a meticulous endeavor, carefully devised to ensure the comprehensive identification of studies of relevance. Employing a mixture of pertinent keywords and controlled vocabulary terms (e.g., Medical Subject Headings or MeSH terms), the search strategy will be tailored to align with the specifications and characteristics of the respective databases—namely, PubMed, Scopus, and Web of Science. The syntax and nuances of the search strategies will be adeptly adapted to harmonize with the intricacies of each database. To construct the search queries, the Boolean operators “AND,” “OR,” and “NOT” will be strategically employed.

The overarching objective of this comprehensive search strategy is to gather a corpus of data that adequately represents the landscape of studies related to virtual simulation, nursing education, knowledge acquisition, and the dynamics of randomized controlled trials (RCTs). This methodology is poised to unearth a robust and diverse collection of studies that will serve as the bedrock for the systematic review and meta-analysis.

### 2.3.1 Search Strategy in PubMed:

The following is an illustrative example of the search strategy that will be employed in PubMed:

1. ("Virtual Simulation" OR "Virtual Reality" OR "Augmented Reality" OR "Serious Games" OR "3D Simulation")
2. ("Nursing Education" OR "Nursing Training" OR "Nursing Curriculum")
3. ("Knowledge Acquisition" OR "Learning Outcomes" OR "Educational Effectiveness")
4. ("Randomized Controlled Trial" OR "Randomized Trial" OR "Clinical Trial, Randomized" OR "RCT")
5. #1 AND #2 AND #3 AND #4

### 2.3.2 Search Strategy in Scopus:

The search strategy in Scopus will be tailored to its syntax and indexing features, and it will resemble the approach taken in PubMed:

1. TITLE-ABS-KEY("Virtual Simulation" OR "Virtual Reality" OR "Augmented Reality" OR "Serious Games" OR "3D Simulation")
2. TITLE-ABS-KEY("Nursing Education" OR "Nursing Training" OR "Nursing Curriculum")
3. TITLE-ABS-KEY("Knowledge Acquisition" OR "Learning Outcomes" OR "Educational Effectiveness")
4. TITLE-ABS-KEY("Randomized Controlled Trial" OR "Randomized Trial" OR "Clinical Trial, Randomized" OR "RCT")
5. #1 AND #2 AND #3 AND #4

### 2.3.3 Search Strategy in Web of Science:

The search strategy in Web of Science will similarly adapt to its search functionality:

1. TS=("Virtual Simulation" OR "Virtual Reality" OR "Augmented Reality" OR "Serious Games" OR "3D Simulation")
2. TS=("Nursing Education" OR "Nursing Training" OR "Nursing Curriculum")
3. TS=("Knowledge Acquisition" OR "Learning Outcomes" OR "Educational Effectiveness")
4. TS=("Randomized Controlled Trial" OR "Randomized Trial" OR "Clinical Trial, Randomized" OR "RCT")
5. #1 AND #2 AND #3 AND #4

### 2.3.4 Additional Search Strategies:

Similar adaptations of the search strategy will be designed for other databases as needed, following the database-specific indexing, syntax, and features.

### 2.3.5 Manual Screening:

In addition to the electronic database searches, manual screening of reference lists from the included studies and relevant systematic reviews will be conducted to identify additional potentially eligible studies.

The search strategy across multiple databases will be carefully crafted to ensure the comprehensive identification of relevant studies for this systematic review and meta-analysis. The use of controlled vocabulary terms, keywords, and Boolean operators will enable a thorough exploration of the literature related to virtual simulation in nursing education and its impact on knowledge acquisition. By employing this rigorous search strategy, we aim to minimize the risk of missing relevant studies and ensure the robustness of the evidence synthesized in this review.

## 2.4 Selection of Studies

A duo of independent reviewers will execute a meticulous two-phase screening procedure. Initially, the screening will encompass the titles and abstracts of potential studies to identify those that meet the preliminary eligibility criteria. Subsequently, the full-text articles of the identified studies will be procured and scrutinized to assess their eligibility against the predefined criteria. Any

discrepancies or disagreements that arise between the reviewers will be amicably resolved through productive discussions or, when deemed necessary, through consultation with a third reviewer.

### 2.5 Extraction of Data

To ensure consistency and standardization, a uniform data extraction form will be devised and employed. This form will facilitate the systematic extraction of pertinent information from the studies that have met the inclusion criteria. Among the data to be extracted are study particulars, participant demographics, details about the intervention, measures of outcomes, and findings pertaining to the effectiveness of virtual simulation in augmenting nurses' knowledge.

### 2.6 Assessment of Bias Risk

The methodological soundness of the included randomized controlled trials (RCTs) will be assessed using the Cochrane Risk of Bias tool. This evaluation will encompass key domains such as the generation of random sequences, the concealment of allocations, blinding of both participants and personnel, the blinding of outcome assessment, the handling of incomplete outcome data, the potential for selective reporting, and any other plausible sources of bias. This assessment of bias risk will be independently undertaken by the two reviewers, and any disparities that arise will be harmonized through thoughtful consensus.

### 2.7 Synthesis and Analysis of Data

The synthesis and analysis of data derived from the amalgamated studies will adhere to a methodical and transparent approach, ensuring the veracity and dependability of the findings. The data harvested from each study will be methodically arranged and subject to appropriate statistical analyses. The chief aim is to evaluate the efficacy of virtual simulation in enriching nurses' knowledge when juxtaposed with conventional educational methodologies or control groups.

#### 2.7.1 Quantitative Synthesis of Data

Should the included studies exhibit a degree of homogeneity pertaining to participants, interventions, and outcome metrics, a quantitative synthesis (meta-analysis) of the data will be undertaken. The choice between

employing fixed-effects or random-effects models will hinge on the observed level of heterogeneity. The magnitude of effects will be presented in the form of standardized mean differences (SMD) or mean differences (MD), alongside their corresponding 95% confidence intervals (CIs).

#### 2.7.2 Evaluation of Heterogeneity

The presence of heterogeneity within the constellation of included studies will be subjected to scrutiny using statistical tools such as the Cochran's Q test and the  $I^2$  statistic. When substantial heterogeneity (where  $I^2$  surpasses 50%) is observed, potential origins will be probed through the prism of subgroup analyses and sensitivity analyses.

#### 2.7.3 Subgroup Analyses

Conducting subgroup analyses will facilitate a systematic exploration of potential sources of heterogeneity and the evaluation of the impact of distinct factors on the overall effect size. These factors may encompass participant attributes (e.g., registered nurses vs. student nurses), the category of virtual simulation (e.g., virtual reality vs. serious games), and the quality of the study (e.g., studies with low vs. high risk of bias).

#### 2.7.4 Sensitivity Analyses

Sensitivity analyses will be carried out to gauge the robustness of the findings. These analyses will involve a scrutiny of the influence of individual studies on the overall effect size. In instances where studies exhibit high bias risk or possess limited sample sizes, their removal from the analysis will be systematic, enabling an evaluation of their impact on the consolidated estimates.

#### 2.7.5 Evaluation of Publication Bias

Potential publication bias will be appraised through the utilization of funnel plots, assuming that a sufficient number of studies are incorporated into the meta-analysis. Should these funnel plots reveal asymmetry, it may indicate the presence of publication bias. Supplementary statistical tests, such as Egger's test, will be employed to quantify the degree of such asymmetry.

## 3. Discussion



The methodology delineated in this protocol is in stringent alignment with the comprehensive guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). This adherence to rigorous guidelines underscores our commitment to minimizing bias, enhancing transparency, bolstering reproducibility, and fortifying the credibility of this systematic review and meta-analysis. The discerning scrutiny of the methodological quality of the studies under scrutiny is poised to provide valuable insights into the overall robustness of the synthesized evidence.

### 4. Assessment of Recommendations via GRADE

In addition to the systematic review and meta-analysis procedures delineated above, the evaluation will encompass the application of the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) methodology. This approach will be harnessed to assess the caliber of evidence and the potency of recommendations drawn from the amalgamated studies.

#### 4.1 Evaluation of Evidence Quality

For each outcome, a comprehensive assessment of evidence quality will be conducted across the ensemble of studies. This evaluation will factor in the following considerations:

##### Bias Risk

The methodological integrity of the studies included will be gauged using the Cochrane Risk of Bias tool. This appraisal will contemplate facets such as random sequence generation, allocation concealment, blinding, management of incomplete outcome data, possible selective reporting, and other potential sources of bias.

##### Heterogeneity

The extent of heterogeneity observed across studies will be examined, with significant unexplained heterogeneity potentially diminishing the quality of evidence.

##### Indirectness

A careful assessment of how congruently the participants, interventions, comparisons, and outcomes in the studies align with the research question will be undertaken.

##### Precision

The precision of effect estimations will be scrutinized, with wide confidence intervals and small sample sizes potentially engendering imprecision.

##### Publication Bias

Potential publication bias will be probed using funnel plots, with its repercussions on evidence quality duly acknowledged.

#### 4.2 Summarized Findings Tables

Each outcome of interest will be encapsulated within a "Summary of Findings" table. These succinct tables will offer a consolidated overview encompassing evidence quality, effect magnitudes, confidence intervals, and a qualitative evaluation of the equilibrium between desirable and undesirable outcomes.

#### 4.3 Strength of Recommendations

Based on the caliber of evidence, deliberations about benefits and detriments, considerations of values and preferences, and assessments of resource implications, the strength of recommendations will be ascertained. The recommendations will be dichotomized as either "strong" or "conditional," effectively capturing the level of confidence in the projected effects.

#### 4.4 Process of GRADE Evaluation

The process of GRADE evaluation will be independently executed by reviewers. In the event of disparities in the assessment of evidence quality or recommendation strength, consensus will be reached through constructive discussions. The transparent documentation of the GRADE evaluation will bolster the final conclusions' dependability and authenticity.

#### 4.5 Conclusion

By assimilating the GRADE approach into the procedural framework of the systematic review and meta-analysis, we aspire to amplify the durability and pertinence of the findings. This GRADE evaluation is slated to offer a comprehensive appraisal of the evidence quality and the robustness of recommendations derived from the confluence of studies. This all-encompassing approach endeavors to facilitate more informed decision-making for nursing educators, practitioners, researchers, and policymakers concerning the amalgamation of virtual

simulation into nursing education and its impact on the enhancement of nurses' knowledge acquisition. Through this holistic endeavor, we are poised to contribute substantively to evidence-grounded nursing education practices and the evolution of healthcare outcomes.

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