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Simulation-Based Education in Undergraduate Nursing Pharmacology: A Systematic Review of Modalities, Effectiveness, and Design Quality

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Abstract: Simulation-based learning is increasingly used in healthcare education; however, limited evidence exists on how it is specifically applied to support undergraduate nursing students in pharmacology. This systematic review aimed to examine the types of simulation modalities used to enhance pharmacology education, evaluate their effectiveness in improving students' medication management, and assess the quality of existing studies. Systematic searches were conducted across seven databases, including Embase, CINAHL, Web of Science, PubMed, and Medline. Of the 3,060 records identified, 127 full-text articles were assessed for eligibility, and 51 studies met the inclusion criteria. Simulation modalities consistently improved pharmacology-related learning outcomes. Studies that incorporated structured pre-briefing, validated assessment instruments, and comprehensive debriefing protocols demonstrated the strongest statistical effects. However, students' perceived self-efficacy in pharmacology was rarely examined, indicating an important gap in the current literature. Overall, effectiveness appeared to be influenced less by the level of simulation fidelity and more by the alignment between the simulation modality, learning objectives, student needs, and educational context. Adherence to best-practice standards recommended by the International Nursing Association for Clinical Simulation and Learning also appeared to strengthen learning outcomes. Simulation-based pharmacology education shows promise for improving medication competence among undergraduate nursing students, although further research is needed to evaluate self-efficacy outcomes and strengthen methodological rigour.

Keywords: simulation-based education, pharmacology, nursing students, medication competence, knowledge.

INTRODUCTION

Simulation-based education (SBE) has become an increasingly important pedagogical approach in healthcare education. Although simulation has a long history in training across disciplines such as aviation and the military, its integration into health professions education, particularly nursing, has expanded significantly in the last two decades with technological advances [1–3]. Within nursing, simulation enables students to practise

clinical and decision-making skills without compromising patient safety, fostering the development of competence, confidence, and critical thinking.

The use of simulation in nursing can be traced back to the early twentieth century, when life-sized mannequins were used to teach essential clinical skills [4,5]. Since then, simulation has evolved into a sophisticated educational method supported by organisations such as the International Nursing Association for Clinical Simulation and Learning (INACSL), which provides evidence-based standards for simulation design and implementation [6,7]. Modern simulation centres now employ a range of modalities, from low-fidelity models to full-scale high-fidelity environments, allowing students to engage in scenario-based training and interdisciplinary teamwork [8].

In nursing education, pharmacology remains one of the most challenging subjects for undergraduate students. Mastery of pharmacological knowledge is essential to ensure safe medication administration and prevent medication errors, which are among the most prevalent causes of adverse patient outcomes [9–11]. Inadequate pharmacological knowledge may compromise nurses' ability to provide accurate information, recognise adverse effects, and ensure safe medication administration. This is particularly concerning in mental health nursing, where patients often receive complex medication regimens and may experience significant side effects [12].

Traditional lectures in pharmacology often fail to provide adequate opportunities for students to apply knowledge in realistic clinical situations [13,14]. Consequently, students may struggle to connect theoretical pharmacological concepts to actual medication administration, dosage calculations, and clinical reasoning. Simulation offers a dynamic alternative, allowing for experiential learning through the enactment of clinical scenarios. Simulated medication practice allows students to apply pharmacological knowledge within realistic clinical decision-making and communication contexts required for safe patient care [15].

Simulation encompasses a variety of modalities (see Table 1), each offering distinct educational advantages. The most commonly employed types in healthcare education include standardised patient simulations, mannequin-based simulations (low-, medium-, and high-fidelity), computer-based or virtual simulations, and hybrid models that combine multiple modalities [16,17].

Recent reviews have demonstrated the effectiveness of simulation-based learning in nursing education. Virtual simulations have been shown to enhance students' knowledge [23], improve technical performance [24], and increase confidence and satisfaction in pharmacology learning [25]. Similarly, high-fidelity simulation has been associated with improved patient safety through enhanced clinical reasoning [26]. However, existing reviews have several limitations. Many focus on simulation in general nursing education rather than pharmacology specifically, examine only selected simulation modalities, or do not evaluate the quality of simulation design. Consequently, there remains limited synthesis of evidence on how simulation is used to support pharmacology education for undergraduate nursing students.

This review therefore extends previous work by analysing how different simulation modalities are implemented in pharmacology education and evaluating their effectiveness and design quality in alignment with evidence-based best-practice standards [14]. Understanding which simulation modalities are being used, their educational outcomes, and

the methodological quality of these studies will help guide curriculum design and inform best practices in nursing education. Accordingly, this systematic review aims to: identify the simulation modalities used in undergraduate nursing pharmacology education; evaluate their effectiveness in improving pharmacological knowledge, competence, and clinical reasoning; and assess the quality of simulation design according to INACSL simulation standards.

Table 1: Simulation Modalities.

1. **Standardized Patient**	Person trained to act ask as "patients" to act out specific clinical scenarios.
2. Mannequins (low, medium and high fidelity)	Model is provided for students to practice with. The model can either be whole or a part of the body.
3. Computer-based	A computer delivers a simulation experience. Students make decisions based on information provided.
4. Mixed/Hybrid Simulation	The use of two or more simulation modalities in the same simulation activity.

METHODS

The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines [27]. PRISMA provides a structured and transparent framework to enhance the reproducibility and quality of systematic reviews. The review protocol was developed prior to data collection, outlining the search strategy, inclusion and exclusion criteria, screening process, and appraisal procedures. Due to the heterogeneity of study designs, simulation modalities, and outcome measures, a meta-analysis was not conducted.

Search Strategy

A systematic search was conducted across seven electronic databases: Medline, CI-NAHL, Embase, Web of Science, Scopus, ERIC, and PsycINFO. The search covered the period from January 2013 to October 2024 to capture contemporary simulation practices following the publication of the INACSL Standards of Best Practice. The search strategy combined controlled vocabulary and free-text terms related to nursing, pharmacology, and simulation. An example of the search string used in Medline was: (nurse OR nursing student*) AND (pharmacology OR medication OR drug*) AND (simulation OR "simulation-based learning" OR "simulation training" OR "simulation-based education")*. Boolean operators and truncation symbols were adapted for each database as appropriate. The search was limited to English-language, peer-reviewed studies involving human participants. Reference lists of included studies and forward citation tracking were also undertaken to identify additional relevant literature.

The initial search yielded 3,060 records, which were imported into Covidence software for screening and duplicate removal. Four reviewers (MM, SA, OO and CM) independently screened titles and abstracts in accordance with PRISMA's four-phase flow

process (Identification, Screening, Eligibility, Inclusion). Disagreements were resolved through discussion, with arbitration by a fifth reviewer when required. Data extraction was conducted using the Joanna Briggs Institute (JBI) data extraction tool for both quantitative and qualitative studies. Extracted data included author and year of publication, country of origin, study design, sample size and participant characteristics, simulation modality, outcomes measured, and key findings. To ensure accuracy and consistency, data extraction was performed independently by two reviewers, with discrepancies resolved by consensus.

Eligibility Criteria

Eligibility criteria were developed using the PICO framework (Participants, Intervention, Comparison, Outcomes): Participants: Undergraduate nursing students enrolled in pre-registration programmes. Intervention: Any form of simulation-based learning used to teach pharmacology or medication administration, including low-, medium-, and high-fidelity mannequins; standardised patient simulations; computer-based or virtual simulations; and hybrid modalities. Comparison: Traditional educational methods such as lectures, video-based instruction, or non-simulation training. Outcomes: Learning outcomes related to pharmacological knowledge, competence, confidence, or clinical reasoning. Exclusion criteria comprised: (a) studies not involving pharmacology education; (b) studies focusing on postgraduate or practising nurses; (c) interventions targeting healthcare professions other than nursing; and (d) publications not available in English or without full-text access. These criteria were applied sequentially during the screening process. Titles and abstracts were initially reviewed, followed by full-text assessments when necessary.

Quality Appraisal

Methodological quality appraisal was undertaken using validated JBI tools. Quantitative studies were assessed using the JBI Meta-Analysis of Statistics Assessment and Review Instrument (JBI-MAStARI), while qualitative studies were evaluated using the JBI Qualitative Assessment and Review Instrument (QARI) [28]. Mixed-methods studies were appraised using the Mixed Methods Appraisal Tool (MMAT) [29]. Each tool evaluates aspects of methodological rigour, including clarity of research aims, appropriateness of design, data collection, validity of measurements, and quality of analysis. Reviewers independently conducted the appraisals, assigning “Yes”, “No”, or “Unclear” responses to each criterion. Any discrepancies were resolved by discussion or adjudication by a third reviewer. All included studies were rated as having low to moderate risk of bias. The appraisal process ensured that each study was assessed against comparable criteria, thereby enhancing the trustworthiness and reproducibility of the synthesis.

Data Synthesis

Given the heterogeneity in study designs, simulation modalities, and outcome measures, a narrative synthesis approach was used. Findings were grouped according to the type of simulation modality and learning outcome (knowledge, competence, confidence, and clinical reasoning). Patterns, consistencies, and divergences were identified and summarised thematically to capture the range and strength of evidence.

RESULTS

Overview of Included Studies

A total of 3,060 records were identified through database searching (Figure 1). After removal of duplicates and screening of titles and abstracts, 127 full-text articles were assessed for eligibility. Of these, 51 studies met the inclusion criteria and were included in the review.

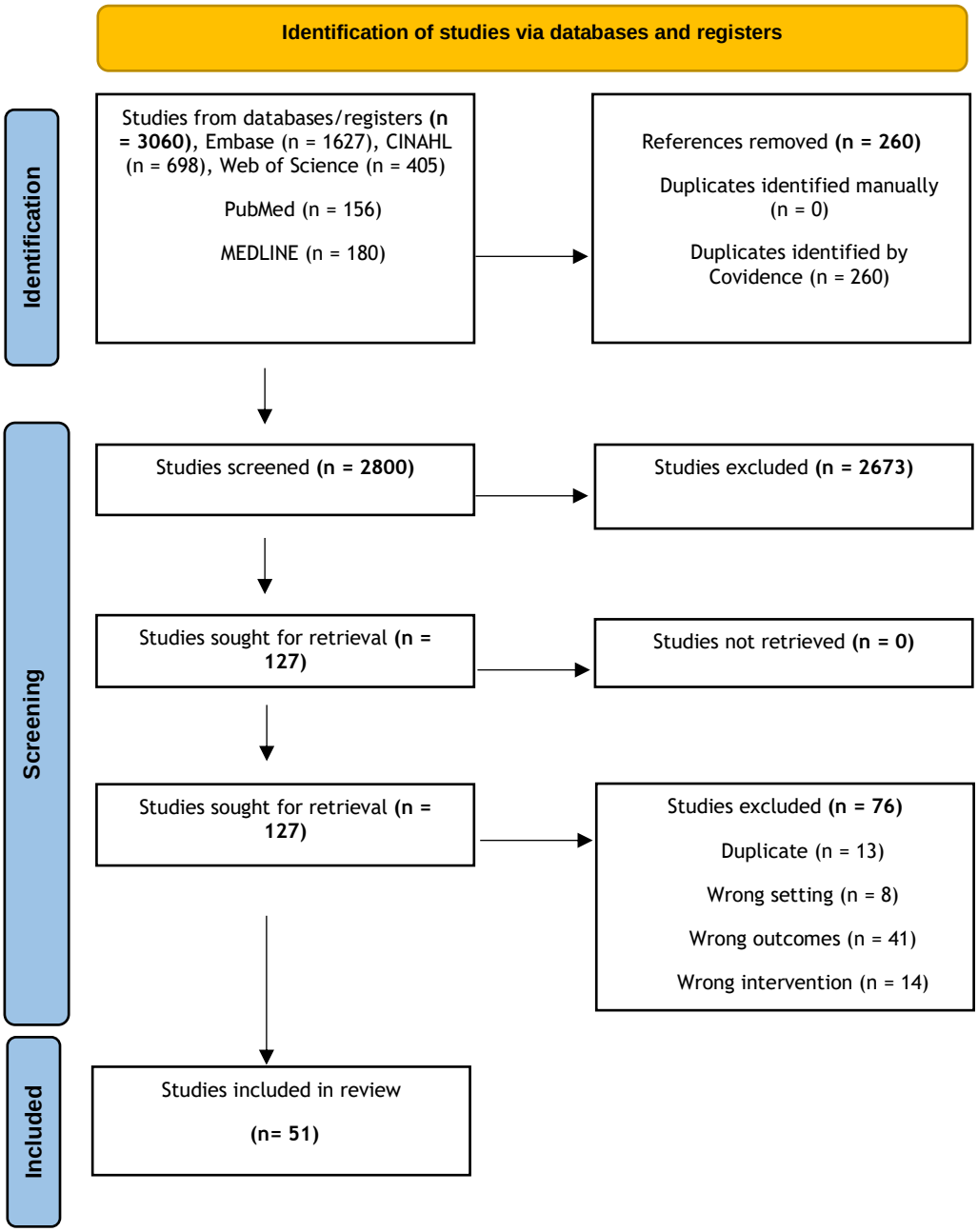

Figure 1: PRISMA Chart

The included studies were conducted across diverse geographical contexts, including the United States, Australia, Israel, the United Kingdom, Turkey, Canada, and Finland, and involved undergraduate nursing students across multiple academic levels. Sample sizes ranged from 10 to 351 participants. Most studies employed quantitative methodologies, including randomised controlled trials, experimental studies, and quasi-experimental

designs, while mixed-methods and qualitative approaches were less frequently represented. Overall, the methodological diversity reflects the varied approaches used to evaluate simulation-based pharmacology education across nursing programmes.

Study Characteristics

Participants

Participants represented multiple stages of undergraduate nursing education. First-year students were included in two studies [30,31], second-year students in six studies [32–37], and third-year students in eight studies [38–45]. Six studies included mixed junior and senior cohorts [46–51], while several studies did not specify the year of study. Only a small number of studies focused on specific nursing specialties, including medical–surgical nursing [52,53], paediatric nursing [54–56], neonatal nursing [57], women's health [58], and anaesthesia nursing [59]. Most studies involved general undergraduate nursing populations.

Geographical Distribution

The majority of studies were conducted in the United States, followed by Australia, Turkey, and Israel. Additional studies were conducted across Europe, Asia, Africa, and South America, including Spain, Finland, Canada, Brazil, India, Morocco, Korea, Namibia, Colombia, Germany, and Iran.

Study Design

Most studies employed quantitative designs. These included randomised controlled trials (n = 5), experimental studies with comparison groups (n = 9), and quasi-experimental designs (n = 14). Additional methodologies included cross-sectional studies, cohort studies, pilot or feasibility studies, mixed-methods research, and qualitative studies. This methodological variation reflects the diverse approaches used to evaluate simulation-based pharmacology education.

Simulation Modalities Used in Pharmacology Education

Across the included studies, multiple simulation modalities were employed to support pharmacology education in undergraduate nursing programmes. These included high-fidelity simulation (HFS), low-fidelity simulation (LFS), standardised patient simulation (SPS), computer-based simulation (CBS), and hybrid simulation models combining multiple modalities.

High-Fidelity Simulation

High-Fidelity Simulation (HFS) was examined in fourteen studies [30,36,40–42,38,71,66,57,48,77,52,49]. In these studies, scenarios were either self-designed to address diverse clinical contexts such as endocrine, cardiac, renal, and transplant care, or adapted from validated sources [41]. Scenarios involved multiple routes of medication

administration, including intravenous, oral, and intranasal delivery. Findings consistently demonstrated that HFS enhanced students' pharmacology knowledge, clinical reasoning, and decision making, particularly in relation to medication safety, dosage calculation, and error recognition [30,38,40]. These results highlight the role of HFS in fostering higher-order cognitive skills and promoting patient safety within nursing education.

Low-Fidelity Simulation

Low-Fidelity Simulation (LFS) was identified in twelve studies [70,42,35,61,63,51,69,64,55,48,73,68]. The primary aim was to strengthen psychomotor skills and procedural confidence while reinforcing principles of safe medication practice. Scenarios incorporated oral, intramuscular, subcutaneous, and intravenous medications. Across studies, LFS was shown to improve basic medication administration skills, error prevention, time management, and adherence to safe techniques [35,42,63]. Studies comparing individual versus group participation reported higher satisfaction and preparedness among students practising individually [70].

Standardised Patient Simulation

Standardised Patient Simulation (SPS) was reported in eleven studies [76,56,37,68,34,55,52,52,58,48,67]. In these studies, trained actors portrayed realistic clinical conditions to enhance students' communication skills, clinical assessment, and decision making in medication-related contexts. Scenarios focused on adverse drug reactions, correct inhaler technique, and home medication management involving medications such as anticoagulants, cardiac drugs, and diuretics. Findings indicated that SPS provided authentic patient interaction and supported the development of communication competence, clinical reasoning, and confidence [56,76]. However, compared with other modalities, SPS was used less frequently and less extensively in pharmacology-focused simulation, suggesting an underutilisation of its potential in medication education.

Computer-Based / Virtual Simulations

Computer-Based Simulation (CBS) appeared in twelve studies [65,74,61,35,53,32,34,69,37,79,31,34. CBS involved virtual or three-dimensional environments designed to allow students to practise medication administration processes digitally. The primary aim was to reinforce the principles of safe medication administration, including recognition of adverse drug events and clinical deterioration. Several platforms simulated realistic medication workflows, including scenarios involving antibiotic-induced anaphylaxis, cardiac arrest, and hypotension management. Medications commonly included antibiotics, insulin, and cardiovascular agents. Across studies, CBS interventions demonstrated improvements in pharmacology knowledge, clinical reasoning, and decision making through interactive design, immediate feedback, and opportunities for repeated practice [35,53,64].

Hybrid Simulation

Hybrid simulations combined multiple modalities appeared in four studies [67,77,52,64], such as mannequin-based scenarios integrated with standardised patient interactions or digital simulation components were examined in four. These integrated approaches were designed to replicate complex clinical situations and provide students with comprehensive experiential learning opportunities [16,17]. Overall, the reviewed literature demonstrates that simulation-based education in pharmacology employs a diverse range of modalities, each offering unique educational advantages. Table 1 summarises the primary learning outcomes assessed across the included studies. Outcomes of interest included competence, knowledge acquisition, confidence, satisfaction, anxiety and stress, and clinical reasoning or clinical judgement.

Table 1: Summary of study designs, simulation interventions, and educational outcomes:

Author(s), Year & Country	Study Method / Population & Sample	Simulation Modality & Intervention *(including sessions & duration)*	Outcomes	Findings	Study Limitations
1. Sarı et al., 2018. Turkey	**RCT** N=23 (e) N=34 (c) 3rd year. Paediatric Nursing.	**HF.** 1 Session. 15–20 minutes. Administer intranasal medication (Nebulizer) to a baby mannequin.	Confidence, Anxiety, stress, & knowledge	No significant knowledge improvement in the experimental (p=0.715). Stress & anxiety were significantly lower in the experimental group (p=0.006 & p=0.033).	Randomization was realized by means of a lottery method.
2. Woroch, and Shinnick, 2023.	**RCT** N=23 family nurse students.	**SP.** The experimental & control group all participated in a different ADR (adverse drug reaction) scenario.	Knowledge.	No significant difference in ADR recognition between experimental and control groups (P=.668).	small sample size.
3. Mahnaz Abdali, Alilu, and Feizi, 2024.	**RCT** N=40 third year nursing students.	**SP.** 1 session. Students were trained to educate patient which included a verbal explanation and hands-on implementation of the inhaler technique.	Confidence.	The intervention group was significantly higher in performance than control group (p<.001).	Convenience sample from one university.
4. Santana & Magro, 2025 Brazil	**RCT** N=60 nursing students.	**HF vs LF.** Students were assigned to experimental group (HF) & control group (LF) to compare the effectiveness of both simulations in acquiring theoretical and practical knowledge.	Knowledge & performance	High-fidelity group showed significant knowledge gain (p < .01). However, practical performance was higher in the low-fidelity group.	Resource heavy; limited to one institution.
5. Mahou et al., 2024 Morocco	**RCT** N=351 nursing students.	**CB.** 4 simulation sessions. SIMDOSE® screen-based simulation for drug calculation and administration; control group paper-and-pencil method.	Knowledge, drug calculation skills & confidence.	Significant increase after the simulation in MAP knowledge (p=0.004), DDC skill (p=0.013), and confidence (p<.001).	Technology issues at some sites.
6. Avraham et al., 2018 Israel	**Experimental.** N=77 Seniors surgical nursing students	**HF.** 1 session. One-on-one simulation for medication administration process.	Critical thinking.	Critical thinking was significantly higher (p=0.05) in the interventional group.	No control group.
7. Hansona, Andersena and Dunn, 2020. Australia	**Experimental.** N=249 2nd year nursing students.	**CB.** 1 session. Duration was not specified. Comparing 3D and 2D pharmacology artefact (CAVE2™) with mobile handheld stereoscopic lenses.	Satisfaction & Knowledge.	Both methods improved satisfaction significantly (P<0.001). However, no significant difference in knowledge.	No random assignments, control group and allocation concealment.
8. Avraham, Shor and Kimhi, 2021. Israel	**Experimental.** N=78 individual sample and N=50 group sample, 3rd	**LF.** 1 session. 2 hours including the debriefing. Medication administration, educate the patient regarding medication reaction and adverse effects.	Satisfaction.	Perceived satisfaction increased in both individual and group samples. Simulation was the main contributor to	Conducted in only one place; observational biases; absence of

	year nursing students.			satisfaction among the individual sample ($p < 0.01$).	interrater reliability.
9. Jarvill et al., 2018. United State	**Experimental.** N=85 first year nursing students	**HF.** 1 session. 30 minutes including the debriefing. Comparing individual simulation experience with traditional practice in medication administration competence.	Competence.	Junior and third year students scored significantly higher after simulation ($p<.001$).	Convenience sample from a single university.
10. Saastamoinen et al., 2022. Finland	**Experimental.** N=71(e), N=52(c)	**CB.** Simulation time & detail was not specified. Experimental group played the 3D simulation game; control group read online material.	Knowledge acquisition.	Pharmacology knowledge increased in both groups, but no significance difference ($p = .541$).	3D game still in development; MCQ limitations; single university.
11. Gisriel, Dalley and Walker, 2021. United State	**Experimental** N=15 Anaesthesia nursing students.	**HF.** 4 sessions. 1 hour including the debriefing. Comparing pharmacology content supplemented with simulation vs traditional lecture.	Knowledge acquisition.	Students scored significantly higher when pharmacology content was supplemented with simulation ($p<.01$).	Convenience and small sample size.
12. Ozdemir and Ulan, 2023.	**Experimental.** N=120 nursing students.	**SP.** 1 session. 8 hours. Students demonstrated inhaler drug use with standardized patients individually.	Knowledge & performance.	Post-test performance score of experiment group was significantly higher ($p <.001$).	Single site study.
13. Tamer & Kavuran, 2025. Turkey	**Experimental** N=64 (e), N=65 (c) Nursing students.	**CB.** Training through a mobile Gamified application designed to improve SC and IM drug administration.	Knowledge & technique.	Significant improvement students' knowledge and skills in administering SC and IM injections for the experimental group ($p < 0.001$).	Small sample, short duration; self-reported data bias.
14. Moss, Nation, & Hall, 2025. US.	**Experimental** N=13 Neonate nursing students.	**HF.** 20-minute period. Escape-room neonatal emergency game to evaluate labs and calculations.	Confidence.	Significant improvement in confidence and faster problem-solving ($P<.05$).	Pilot; small sample; novelty effect; single university.
15. Coskun and Sendir, 2022. Turkey	**QE.** N=81 first year nursing students	**HS (CBS+SP).** 1 session. In CBS, students watched interactive skills videos on intramuscular medication administration skills. In the hybrid simulation, an actor played a standardized patient role and students practiced injecting skill.	Knowledge and anxiety.	Both methods improved knowledge but no significant differences ($p=0.056$). No statistically significant difference between anxiety levels ($p>0.05$).	Sample from a single location.
16. Craig et al., 2021. VA. US	**QE.** N=45 (e), N=35 (c) 3rd year nursing students.	HF. 1 session. 1 hour including the debriefing.	Knowledge acquisition.	Experimental group had significantly higher knowledge than control ($p < .001$).	Convenience sample from a single university.
17. Brauneis et al., 2021. Chicago, US	**QE.** N=44.	LF. 1 session. 1 hour for entire simulation.	Knowledge & confidence.	Experimental group significantly improved knowledge ($p = 0.01$) and confidence ($p = .045$).	Convenience small sample from a single university.
18. Aggar et al., 2018. Australia	**QE**. N=180 2nd year nursing students.	**LF**. 1 session. 1.5 hour for entire simulation. Time management activity using simulation on medication administration.	Confidence.	No significant difference in confidence improvement ($p = 0.708$).	Lack of follow-up and inability to match all pre and post-test surveys.
19. Mager & Campbell, 2013. Canada	**QE**. N=60	**SP.** Students in experimental group individually calculated drug dosages during the simulation. Simulation stages were not specified.	Confidence & Knowledge.	Significant increase in confidence ($P<.01$) and knowledge ($p=.02$).	Convenience sample from a single university.
20. Yu and Fang, 2023. Korea	**QE**. N=109 (e), N=84 (c)	**CB.** Students attended virtual microlecture module for a nursing course in medication administration.	knowledge & satisfaction	Treatment group performed better than the control group ($P < .01$).	Single site study.
21. Yalcinturk and Stun, 2022.	**QE.** (n =41) control (n =41)	**HF.** Students were requested to identify 10 medical errors on psychiatric case scenario.	Knowledge MCQ.	The intervention group was higher than the students in the control group ($p <0.05$).	Single site study.

22. Shor, Kimhi and Avraham, 2024. Israel	**QE.** Third-year nursing students (N=63)	**LF.** 1 session. Participated in simulation for medication administration. Participants' errors were documented.	confidence administration safety	Confidence in error reporting after simulation increased significantly ($p < 0.01$).	In one place.
23. Ramamurthy, Chitra & Kavitha, 2024. India	**QE.** N=50 (e), N=100 (c), 4 nursing colleges.	**HF.** 1 week duration. Compare simulation vs traditional teaching in prevention of medication error.	Knowledge & attitude.	Significant improvement in level of knowledge & attitude in the simulation group ($p<0.05$).	Instructor bias.
24. Shahzeydi et al., 2025. Iran	**QE.** N=64 3rd year nursing students.	**LF.** Compare medication error encouragement training and low-fidelity simulation.	Competence & Knowledge.	Significant increase in the knowledge & competence for the medication error encouragement training group ($P < 0.05$).	No long-term follow-up and self-report bias.
25. Schroers et al., 2025. US	**QE.** N=60 nursing students over 4 sites.	**HF.** 8 sessions. 10 mins each. Deliberate practice of medication administration across 8 scenarios.	Competency.	Improved medication administration scores; error rate reduced from 86% to 7%.	Site variability; inconsistent instructor delivery; heterogeneous sample.
26. Campbell et al., 2023.	**QE.** N=101	**LF** 1 session 1 hr for the entire simulation. Examine the impact the use of low fidelity simulation combined with either virtual simulation or traditional paper case on safe medication administration.	Competence	No significant difference between the VS groups compared with the traditional paper case study groups ($P=.06$)	Single sire study.
27. Thomas et al., 2024. USA	**QE.** N=19 nursing students	**LF.** OSCE-based intravenous medication administration simulation.	Confidence.	Significant increase in self-confidence ($p < .05$).	Small sample; pilot; increased program costs.
28. Tourtual & Ludan, 2025. USA	**QE.** N=28 (e), N=19 (c) nursing students.	NA. Simulation vs traditional education to evaluate medication reconciliation knowledge and skills.	Knowledge & attitude.	Significant improvement in knowledge and reconciliation accuracy after simulation ($p<.05$).	Small sample, non-equivalent groups, limited diversity.
29. Sanabria et al., 2025. Colombia	**QE.** N=42 (c), N=46 (e).	**CB.** 3 sessions. Virtual simulation competence in paediatric drug administration compared to conventional instruction.	Competence.	Experimental group scored higher but was not significant ($P=0.57$).	Small sample size and single site.
30. Heier et al., 2024 . Germany	**QE.** N = 221 nursing students.	**PS.** 3 sessions. Interprofessional simulation-based communication skills training using simulation persons focused on medication error communication.	Error Communication &teamwork.	Significant improvements observed ($p < .001$; $p = .012$).	Non-randomised pilot design; uneven sample sizes.
31. Meginniss et al., 2024. USA	**QE.** N =166 students.	**HF.** 7 sessions. QR scanning vs standard manual medication administration for vulnerable populations.	Medication errors.	No statistically significant difference between groups.	Non-randomised allocation; single site.
32. Schneidereith, 2021. US	**Cohort.** N=78 nursing students.	**HF.** 4 consecutive semesters. 13-15 minutes. Students observed for performance during simulation experiences.	Competence	80% of students did not verify all five rights before administration.	No control group; no pre and posttest.
33. Foss & Morandini, 2023. US	**Cohort.** N=168 nursing students.	**LF.** 2 sessions. OSCE medication rights scenario scored by faculty.	Knowledge.	Greater than 90% pass rate on first attempt; 100% on second attempt.	In one site.
34. Corvino, 2025. US	**Cohort** N=52 students.	**HF, LF & SP.** 8 sessions. Multipatient simulation using mixed fidelities.	No quantitative data collected.	Students managed complex scenarios effectively.	No control group; no quantitative analysis.
35. Fusco et al., 2021. Cleveland OH	**Cross-sectional.** N=98 junior, N=90 senior	**LF.** 1 session. 10 minutes. Six rights of medication evaluation.	Competence.	Competence improved in both groups; seniors not higher than juniors ($p>0.05$).	Different cohorts.
36. Lee and Wessol, 2021. US	**Cross-sectional.** N=29 students.	**CB.** 1 session. 1.5 hour video simulated scenario.	Clinical judgment.	Clinical judgment significantly correlated with best practices ($P=.018$).	Small sample size.

37.	East & Hutchinson, 2015. Australia	**Cross-sectional.** N=32 nursing students.	**CB.** Simulation detail not specified. Filmed pharmacological scenario.	Critical thinking.	Simulation enhanced critical thinking skills.	Small sample size.
38.	Buck Sainz-Rozas et al., 2025. Spain	**Cross-sectional.** N = 224 2nd-year nursing students.	**CB.** Gamified medication calculation contest; multi-phase intervention.	Competence.	Medication calculation competence very low; 99% failed to reach passing level.	Non-validated assessment instrument.
39.	Edwards, Williams and Lee, 2019. UK	**Qualitative** Sample not specified.	**SP.** 1 session. Four case scenarios requiring medication administration.	Knowledge & confidence.	Three themes identified: realism, leading the moment, challenged.	Sample not specified.
40.	Marvanova and Henkel, 2018. Finland	**Qualitative.** N=69 nursing students.	**HF.** 1 session. Recognition of medication errors.	Questionnaire on preventable medication errors and self-reported learning benefits.	88.4% strongly agreed simulation was useful and accurate.	Single institution; subjective evaluation.
41.	Saastamoinen et al., 2024.	**Qualitative.** Sample size not specified.	**CB.** 1 session. Simulation game in authentic hospital environment.	Semi-structured group interviews.	Three themes identified: medication process learning methods, prerequisites for the simulation game, and application of different medication process learning methods.	Sample size not specified.
42.	Alfonso-Arias et al., 2025. Spain	**Qualitative**. N=24 nursing students.	**LF and SP.** 4 focus groups over six weeks. Simulation-based training on safe medication administration.	Focus groups.	Two themes identified: usefulness of the clinical simulation for acquiring, competence in safe medication administration. & elements of simulation design that foster learning.	Single site.
43.	Tomas & Fillipus, 2024. Namibia	**Qualitative.** N=10 nursing students.	**NA.** Exploration of self-reported perceptions of competence.	Semi-Structured Interviews.	Four themes identified. fear, weak pharmacology knowledge, low dosage-calculation confidence, inadequate supervision.	Small sample & subjective perceptions.
44.	Pence, 2022 Illinois. US	**Mixed-methods.** N=28 nursing students.	**CB.** Virtual Simulation using vSim for Nursing pharmacology scenarios.	Satisfaction & confidence.	VS perceived as helpful; difficulty navigating reported.	Convenience sample from one university.
45.	Foronda et al., 2018. US	**Mixed-methods.** N=99 nursing students.	**CB**. 1h 45 minutes. vSim for Nursing Medical-Surgical package.	Satisfaction & competence.	77% preferred virtual simulation to enhance lectures.	Single site; limited debriefing time.
46.	Hansona, Andersena and Dunn, 2019. Australia	**Mixed-methods.** N=202 2nd nursing students.	**CB.** Lecture followed by 2D or 3D simulation exposure.	Knowledge acquisition & satisfaction.	3D experience significantly improved knowledge (P<0.01).	Authority prevented use of control group.
47.	Murphy & Sweeney, 2023.	**Pilot** N=37 junior nursing students.	**HF.** 1 session. 45-minute. Dosage calculation error scenario.	No measurement tool specified.	No measurement tool specified.	No tool specified.
48.	Murphy, Sweeney & Lugo, 2025. US	**Pilot.** N not reported.	**NA.** 4 semesters. Simulation-based dosage calculation assessment integrated into CBE.	Competency.	All students achieved ≥90%.	Pilot study; no control group; sample size not reported.
49.	Schroers et al. (2024). US	**Pilot.** N = 19 nursing students.	**LF & SP** 1 semester (6 hrs. each week), medication administration with interruptions. Intervention group received interruption management education (Stay SAFE strategy), control group received medication administration education only.	Confidence.	increased confidence in handling interruptions after learning the strategy.	Feasibility study, conveniene small sample size and single-site.
50.	Neerland et al., 2025. US.	**Pilot** N = 20 nursing students	**SP.** 30 mins. Counseling on medication abortion.	Confidence.	High satisfaction and perceived preparedness.	Small sample; no control group.
51.	York et al., 2025. US.	**Pilot** N = 102 students	**LF and CB.** 1 session. 3 hrs. Medication administration and error identification using	Satisfaction & confidence.	Increased satisfaction and self-confidence.	No control group; self-reported outcomes.

		mannequins and simulated EHR.			

(e)=experimental group; (N)=number (c)= control group; (RCT)=randomised controlled trial; (QE)= quasi experimental. (HF)=High Fidelity; (LF)= ;(CB)= computer based;(SP)=standardised patient; (HS)= Hybrid Simulation

Effectiveness of Simulation-Based Pharmacology Education

The effectiveness of simulation-based pharmacology education was evaluated across a range of objective and subjective outcomes, including competence in medication management, pharmacological knowledge, clinical reasoning, confidence, satisfaction, and stress or anxiety levels.

Competence in Medication Management

Several studies reported improvements in students' medication-management competence following simulation-based learning interventions. Across modalities including high-fidelity, low-fidelity, computer-based, and hybrid approaches, significant gains in medication administration competence were reported in some studies ($p < .001$) [26,28]. Low-fidelity simulation also contributed to improved technical skills related to medication administration and dosage calculation; however, these improvements were often not statistically significant ($p > .05$) [29]; ($p > .05$) [73]. Similarly, low-fidelity simulation combined with virtual simulation showed improvement compared with paper-based cases, although the difference did not reach statistical significance ($p = 0.06$) [74].

Pharmacological Knowledge

Knowledge improvement was reported across several simulation modalities. Significant gains were observed following high-fidelity, low-fidelity, and virtual simulations ([28], $p < .001$; [75], $p < .001$; [35], $p < .01$; [76], $p < .01$). In contrast, some studies reported non-significant changes in knowledge outcomes ([29], $p = .01$; [39], $p = .668$; [38], $p = .715$; [42], $p > .05$).

Clinical Reasoning and Critical Thinking

High-fidelity simulation uniquely enhanced critical thinking, with significant scores reported ($p < .001$) [77]. Virtual simulation improved clinical judgment, with a significant correlation observed between clinical reasoning and safe medication practice ($p = .018$) [79].

Student Confidence and Satisfaction

Both low-fidelity and standardized patient modalities effectively improved confidence in medication administration. Higher post-test confidence was observed in the intervention group ($p < .01$) [80]. Similar improvements were also reported ($p = .045$) [29] and ($p < .01$) [76]. Both virtual and low-fidelity modalities also enhanced satisfaction with simulation experiences, with significant gains reported ($p < .01$) [35], ($p < .01$) [77], and ($p < .01$) [33].

Anxiety and Stress

High-fidelity simulation reduced stress and anxiety ($p = 0.006$; $p = 0.033$) [38], while computer-based and hybrid simulation showed non-significant differences ($p > 0.05$) [42].

Quality of Simulation Design

The quality of simulation design was assessed using selected standards from the INACSL guidelines, including the presence of structured pre-briefing [6,7], scenario design, and debriefing. Overall, adherence to INACSL best-practice standards was inconsistent across studies. Some studies clearly reported structured simulation designs that included orientation sessions, defined learning objectives, and guided reflection through debriefing. These studies generally reported stronger educational outcomes. However, many studies provided limited detail regarding simulation preparation, scenario development, or debriefing processes. Debriefing approaches varied widely, with only a minority of studies describing formal debriefing frameworks or validated reflection methods. Since debriefing is widely recognised as a critical component of simulation-based learning, inconsistent reporting represents a limitation in the current evidence base.

DISCUSSION

Simulation-based education (SBE) has become an essential component of contemporary nursing curricula, enabling students to integrate pharmacological theory into clinical practice while minimising patient risk [13,51]. This review synthesised evidence across three objectives: identifying simulation modalities used in undergraduate nursing pharmacology education, determining their effectiveness, and evaluating adherence to INACSL Standards of Best Practice. Collectively, the findings indicate that simulation is a valuable pedagogical strategy for improving medication safety, pharmacology knowledge, and learner confidence. However, its effectiveness depends on how simulation is designed, implemented, and evaluated [56].

Simulation Modalities Used in Pharmacology Education

The review demonstrates that multiple simulation modalities can effectively support pharmacology learning when aligned with learning objectives and learner level [4]. High-fidelity simulation (HFS) offers realistic, scenario-based training that supports complex decision making, while standardised patient simulation (SPS) strengthens communication and clinical reasoning in medication-related contexts [37,78]. Low-fidelity simulation (LFS) primarily develops psychomotor and procedural skills, and computer-based/virtual simulation (CBS) provides scalable, feedback-rich environments that enhance engagement and accessibility [53,64]. Importantly, effectiveness did not depend on a single modality but on fit-for-purpose design, reinforcing the need for a multimodal curriculum approach [56].

Many scenarios emphasised procedural accuracy (e.g., the “six rights” of medication administration). While foundational, this focus often neglected broader elements of medication management such as communication, data interpretation, and clinical reasoning [3,76]. Consistent with prior work, competent nursing practice requires integrating

psychomotor skills with critical thinking and reflective practice [3]. Few studies assessed learners' ability to identify medication errors or apply reasoning in complex contexts, highlighting an ongoing theory–practice gap [66].

Effectiveness of Simulation-Based Pharmacology Learning

Findings from this review indicate that simulation-based education positively influences nursing students' medication administration skills across multiple outcome domains, with the majority of included studies reporting improvements in competence, knowledge acquisition, confidence, satisfaction, and, less consistently, clinical reasoning [29,45,78]. Among the various modalities, High-Fidelity Simulation (HFS) emerged as the most frequently investigated and consistently effective approach. Evidence demonstrated that HFS enhances pharmacological knowledge, clinical competence, critical thinking, and emotional regulation, particularly in complex, high-stakes scenarios that closely resemble real clinical environments [5,7]. These findings reinforce earlier research indicating that HFS supports the integration of theoretical pharmacology knowledge into practice by allowing students to rehearse decision making, prioritisation, and error recognition within a safe but realistic context [5,76]. Furthermore, the use of HFS has been associated with improved patient safety outcomes and reductions in medication-related errors, although its implementation across pre-registration nursing curricula remains inconsistent and often constrained by resource and staffing limitations [7,76]. Qualitative evidence suggests that students perceive HFS as instrumental in consolidating theoretical understanding, teamwork, and clinical judgement, highlighting its pedagogical value for fostering safe, evidence-based medication practices [78].

Standardised Patient Simulation (SPS), although less frequently employed within pharmacology-focused education, demonstrated meaningful improvements in students' confidence and knowledge [4,37,78]. This aligns with broader literature emphasising the role of SPS in enhancing communication skills, empathy, and clinical competence through authentic patient interaction [37,60]. The emotional engagement and realism inherent to SPS support learning across cognitive, affective, and psychomotor domains, distinguishing it from mannequin-based or purely virtual simulations. Importantly, evidence from this review suggests that SPS may be particularly valuable in specialised areas such as mental health nursing, where therapeutic communication, emotional awareness, and interpersonal skills are integral to safe and effective medication management [4].

Computer-Based/Virtual Simulation (CBS) produced knowledge outcomes comparable to traditional teaching approaches, supporting the view that CBS should complement rather than replace face-to-face simulation or clinical instruction [64,35]. Consistent with previous reviews, no significant differences were observed in pharmacology knowledge gains between CBS and traditional teaching [64,35]. However, both the included studies and wider literature highlight that the principal strength of CBS lies in its capacity to enhance student satisfaction, confidence, and engagement rather than direct knowledge acquisition [35]. Students frequently described computer-based simulations as engaging, accessible, and motivating, with these attributes linked to improved learning experiences. The high levels of satisfaction associated with CBS may be attributed to its visualisation capabilities, flexibility, and suitability for self-directed learning, particularly when delivered via mobile or online platforms. Nevertheless, limitations remain, including

reduced opportunities for team communication and interprofessional interaction—key elements of clinical simulation—which may restrict the development of collaborative skills unless CBS is supplemented with guided reflection or group-based discussion [35].

Low-Fidelity Simulation (LFS) was shown to improve confidence, satisfaction, and, in some cases, knowledge acquisition; however, its impact on measurable clinical competence and higher-order reasoning was limited [60]. These findings are consistent with previous research suggesting that LFS supports foundational learning and procedural familiarity but lacks the complexity required to develop advanced clinical judgement. Notably, greater satisfaction and perceived preparedness were reported when LFS activities were conducted individually, allowing students full engagement with each step of medication preparation and administration. In contrast, group-based formats appeared to dilute active participation and learning opportunities [60]. LFS appears well suited for early-stage skill development but less effective for fostering complex decision making compared to more interactive or immersive modalities.

Despite frequent reports of increased "confidence," few studies employed validated measures of self-efficacy in pharmacology education. As self-efficacy reflects belief in one's capability to perform medication-related tasks rather than general confidence, this conceptual mismatch limits interpretation of simulation outcomes. The use of validated, task-specific self-efficacy instruments in medication learning is therefore essential [6].

Quality of Simulation Design

The findings of this review demonstrate that, although the majority of included studies implemented simulation experiences that broadly aligned with the International Nursing Association for Clinical Simulation and Learning (INACSL) Standards of Best Practice: Simulation℠, adherence to all core components of high-quality simulation design—namely pre-briefing, scenario fidelity, debriefing, and evaluation, was inconsistent across the evidence base [64]. This pattern reflects trends reported in the wider simulation literature, where variability in educator preparation, institutional resources, and organisational priorities often results in uneven application of evidence-based simulation practices [76,64]. Consistent with previous research, studies that incorporated structured pre-briefing and evidence-informed scenario design demonstrated clearer alignment between learning objectives and learner performance outcomes, reinforcing the principle that simulation effectiveness is intrinsically linked to pedagogical design quality and contextual fit [64].

Despite the widespread inclusion of debriefing sessions following simulation activities, relatively few studies employed structured, evidence-based debriefing models, such as PEARLS, Debriefing with Good Judgement, or the GAS framework. This mirrors findings from prior reviews indicating that, although debriefing is universally recognised as a cornerstone of learning in simulation-based education, the quality, structure, and theoretical underpinning of debriefing practices remain inconsistent [77]. Within this review, only one study systematically evaluated written reflection as part of the debriefing process, aligning with broader evidence that reflective practice promotes deeper learning, enhances self-awareness, and supports safer clinical decision making [60]. The limited integration of structured reflection and formalised debriefing frameworks therefore

represents a missed opportunity to strengthen students' integration of theoretical pharmacology knowledge with clinical reasoning and practice.

Several methodological and contextual limitations were evident across the included studies. Only 26 studies assessed effectiveness, with fewer than two-thirds reporting statistically significant outcomes, highlighting limited experimental rigour within the current evidence base. High-fidelity simulation (HFS) was disproportionately represented, potentially inflating perceptions of its effectiveness relative to other modalities. Many studies lacked standardised assessment tools or failed to clearly distinguish between confidence, competence, and self-efficacy, resulting in conceptual ambiguity. In addition, few studies differentiated between active participants and observers, limiting understanding of how engagement level influences learning outcomes. Small sample sizes, single-institution recruitment, and short-term post-tests further constrained the generalisability and sustainability of findings. Only one study employed a validated post-simulation evaluation framework [42], restricting cross-study comparability and objective outcome measurement. Inconsistent reporting of simulation duration, group size, and faculty-to-student ratios further undermines replicability [4]. Finally, logistical and financial constraints, including limited faculty expertise, inadequate technical support, and insufficient simulation capacity, remain significant barriers to scaling simulation-based learning [58].

The included studies demonstrated generally moderate to high methodological quality. Most quasi-experimental, experimental, and randomised controlled trials met key criteria related to outcome measurement and statistical analysis, although several studies showed unclear or high risk in domains related to confounding and blinding. Cross-sectional studies generally demonstrated lower methodological risk within the assessed domains. Qualitative and mixed-methods studies largely met criteria related to methodological coherence and data integration, with some variability observed in researcher reflexivity and integration processes.

IMPLICATIONS

The evidence consistently indicates that no single simulation modality is universally superior; rather, effectiveness depends on alignment with learning objectives, learner level, and educational context [4,60]. A multimodal simulation framework—progressing from LFS to HFS and standardised patient simulation (SPS) and supplemented by CBS/VS—can support the progressive development of psychomotor, cognitive, and affective competencies across the curriculum. Faculty development and sustained institutional investment are essential to ensure consistent, evidence-based simulation design, facilitation, and debriefing aligned with best-practice standards [51,56].

At the research and policy level, future studies should prioritise robust experimental designs, standardised reporting of simulation characteristics, and the use of validated outcome measures, particularly for self-efficacy and clinical reasoning [6]. Longitudinal follow-up is needed to evaluate retention and transfer of learning to clinical practice, while policy frameworks should promote equitable access to diverse simulation modalities to prevent resource constraints from limiting educational quality. Addressing these priorities will strengthen the evidence base, enhance comparability across studies, and support a high-

quality, context-driven approach to simulation-based pharmacology education that advances medication safety.

CONCLUSION

This systematic review demonstrates that simulation-based education effectively enhances pharmacology knowledge, medication competence, and patient safety in undergraduate nursing education. Effectiveness was driven not by simulation modality alone but by purposeful alignment between design, learning objectives, learner level, and context. While high-fidelity, virtual, standardised patient, and low-fidelity simulations each supported distinct learning outcomes, multimodal approaches remain underexplored. Greater adherence to simulation best-practice standards and the use of validated outcome measures, particularly self-efficacy, are needed to strengthen the evidence base and support safe medication practice.

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