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Interventions to improve technical and non-technical skills of nurses working in operating theatres: A scoping review with evidence gap mapping

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ABSTRACT

Background: Operating room nurses must master a wide spectrum of technical and non-technical skills to ensure patient safety and high-quality care. Although numerous interventions have been developed and implemented, evidence is fragmented and inconsistent.
Aim: To map interventions aimed at improving technical and non-technical competencies of operating room nurses, describe outcome measures, and identify evidence gaps.
Design: Scoping review following the Arksey and O'Malley framework.
Methods: We searched PubMed, CINAHL, Scopus, and EMBASE for primary studies and reviews involving registered operating room nurses (scrub, circulating, perioperative). Data extraction covered study characteristics, interventions, competencies targeted, instruments used, and outcomes. We applied vote-counting to summarize direction of effects and used a harvest plot and evidence gap map to visualize findings and research gaps.
Results: 21 studies met the inclusion criteria. Most evaluated educational interventions ($n = 19$), with 16 (84.2%) positive and three (15.8%) mixed results, while behavioral (n = 1) was positive (100%) and the organizational study (n = 1) showed a mixed effect. By competency domain, technical skills ($n = 7$) were mainly positive (85.7%), non-technical skills ($n = 3$) showed more variability (33.3% positive, 66.7% mixed), and studies addressing both domains ($n = 11$) were largely positive (90.9%); no null effects were reported. Outcome and instruments heterogeneity were common limitations.
Conclusion: Evidence indicates that educational interventions, particularly simulation-based training and blended curricula, effectively improve operating room nurses' competencies. However, organizational and system-level strategies remain underexplored, and evaluations of non-technical skills are inconsistent. Future research should prioritize rigorous comparative designs, standardized outcome measures, and long-term, multicenter evaluations to strengthen the evidence base.
Implications for the profession and patient care: Targeted educational interventions can enhance operating room nurses' competencies, while greater attention to non-technical and organizational skills is needed to further improve patient safety and quality of care.

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1. Introduction

The operating room (OR) is a highly dynamic and technologically advanced environment where nurses play a pivotal role in ensuring patient safety and maintaining efficient surgical workflows (Chellam Singh & Arulappan, 2023). Beyond technical expertise in aseptic technique, instrumentation, and surgical preparation, OR nurses must demonstrate robust non-technical skills (NTS), including communication, teamwork, situational awareness, decision-making, and leadership, all of which are critical to preventing adverse events and optimizing outcomes (Uçak & Cebeci, 2021). As surgical procedures become increasingly complex and the adoption of digital, robotic, and artificial intelligence (AI)-supported technologies accelerates, the set of skills and competencies expected of OR nurses is constantly evolving and expanding (Gonzalo de Diego et al., 2024; Senol Celik et al., 2023).

Over the last decade, a wide range of interventions has been developed to strengthen both technical and non-technical competencies of OR nurses. These include educational initiatives such as simulation-based training, e-learning modules, and comprehensive curricula (e.g., Periop 101), as well as organizational interventions such as workflow redesign, team-based crisis resource management training, and standardized hand-off protocols (Pai et al., 2024; Robertson et al., 2017; Stucky et al., 2024). Although individual studies consistently report improvements in knowledge, confidence, and adherence to best practices (Kaldheim et al., 2019; Mohammadi et al., 2025), the evidence base is highly heterogeneous. Variability exists in the conceptualization of perioperative competence (Gillespie et al., 2018), the types and intensities of interventions, the tools used for assessment, and the outcomes measured (Heidarpoor et al., 2021). Moreover, despite this growing body of research, synthesis efforts remain scarce. Consequently, current knowledge is fragmented, and decision-makers lack a comprehensive map of available interventions, the competencies they target, and the outcomes they influence. Without such synthesis, educators and managers may struggle to identify which training approaches best address actual competence gaps, evaluate the effectiveness of existing educational strategies, or design professional development initiatives aligned with organizational and patient safety priorities. This limits the ability of nursing educators, managers, and policymakers to make evidence-informed decisions about workforce development and quality improvement strategies.

To address these gaps, we conducted a scoping review with the aim of mapping interventions designed to enhance OR nurses' technical and non-technical skills, identifying instruments and methods used to assess competencies, and highlighting under-researched areas that warrant further investigation.

2. Methods

2.1. Design

This scoping review and evidence gap mapping followed the five-stage methodological framework proposed by Arksey and O'Malley (2005) and refined by Levac et al. (2010), and was reported in accordance with the PRISMA Extension for Scoping Reviews (PRISMA-ScR) checklist (Tricco et al., 2018).

2.2. PCC framework

Eligibility criteria were developed using the Population-Concept-Context (PCC) framework. The population of interest comprised registered OR nurses, including scrub and circulating nurses. Nursing students and other health professionals were excluded unless data specific to OR nurses were reported separately. The concept focused on interventions explicitly designed to improve technical or non-technical competencies of OR nurses (Rosendal et al., 2023), classified according to the Cochrane Effective Practice and Organization of Care (EPOC) taxonomy (Practice & Care, 2016). Interventions that targeted only patient outcomes, infrastructure, or costs were not considered. The context was limited to hospital-based surgical and perioperative settings, with emphasis on post-licensure or in-service professional development; academic-only or pre-licensure training contexts were excluded.

2.3. Eligibility criteria

Inclusion criteria comprised quantitative or mixed-methods studies with at least one comparison group (e.g., randomized controlled trials, quasi-experimental designs, controlled before–after studies) published in English or Italian, with no restrictions on publication year. Exclusion criteria included qualitative-only studies, quality improvement projects without a defined intervention design, and studies targeting nurse managers were excluded. Studies limited to checklists or turnover procedures, editorials, commentaries, opinion pieces, and protocols without empirical data were also excluded. Pilot or feasibility studies that focused solely on acceptability or preliminary functioning of interventions, without reporting substantive outcomes, were likewise excluded. Qualitative studies were excluded because our aim was to map comparative evidence on intervention effectiveness, which requires quantifiable outcomes. Although valuable for understanding experiences, qualitative designs do not permit assessment of direction of effect. Similarly, quality improvement projects without a defined intervention structure were excluded, as they often lack methodological rigor, reproducibility, and comparable outcome measures.

2.4. Information sources and search strategy

A comprehensive literature search was performed in four electronic databases: PubMed (NLM), CINAHL (EBSCOhost), Scopus (Elsevier), and Embase (Elsevier). In addition, PROSPERO was searched to identify ongoing or recently registered systematic reviews. Database-specific controlled vocabulary terms (e.g., MeSH, CINAHL Headings, Emtree) and free-text keywords were combined using Boolean operators. Detailed search strings for each database are provided in Appendix A.

2.5. Selection of sources of evidence

All records were imported into Rayyan software for screening and deduplication. The selection process was conducted in two phases: (i) title and abstract screening, and (ii) full-text screening. Both phases were performed independently by two reviewers. A pilot screening of 20 records was conducted to calibrate application of eligibility criteria. Discrepancies were resolved through discussion or by consulting a third reviewer. At the full-text stage, studies were excluded if they did not meet the predefined eligibility criteria (e.g., population, exposure, or outcomes not relevant to the review question). Reasons for exclusion at the full-text stage were documented. The study selection process is presented in a PRISMA-ScR flow diagram (Fig. 1).

2.6. Data charting

Data were extracted using a standardized Excel form developed by the review team and refined following a pilot phase. Two reviewers independently charted data, with disagreements resolved by consensus or a third reviewer. Extracted variables included: study characteristics (author, year, country, design), population details (sample size, nurse roles), intervention characteristics (type, duration, features), competencies targeted (technical and non-technical), assessment instruments and methods, reported outcomes, and main results. Technical skills were defined as procedural or task-specific clinical competencies required to perform healthcare interventions, whereas non-technical skills referred to cognitive, social, and interpersonal abilities such as communication, teamwork, leadership, and decision-making that support effective

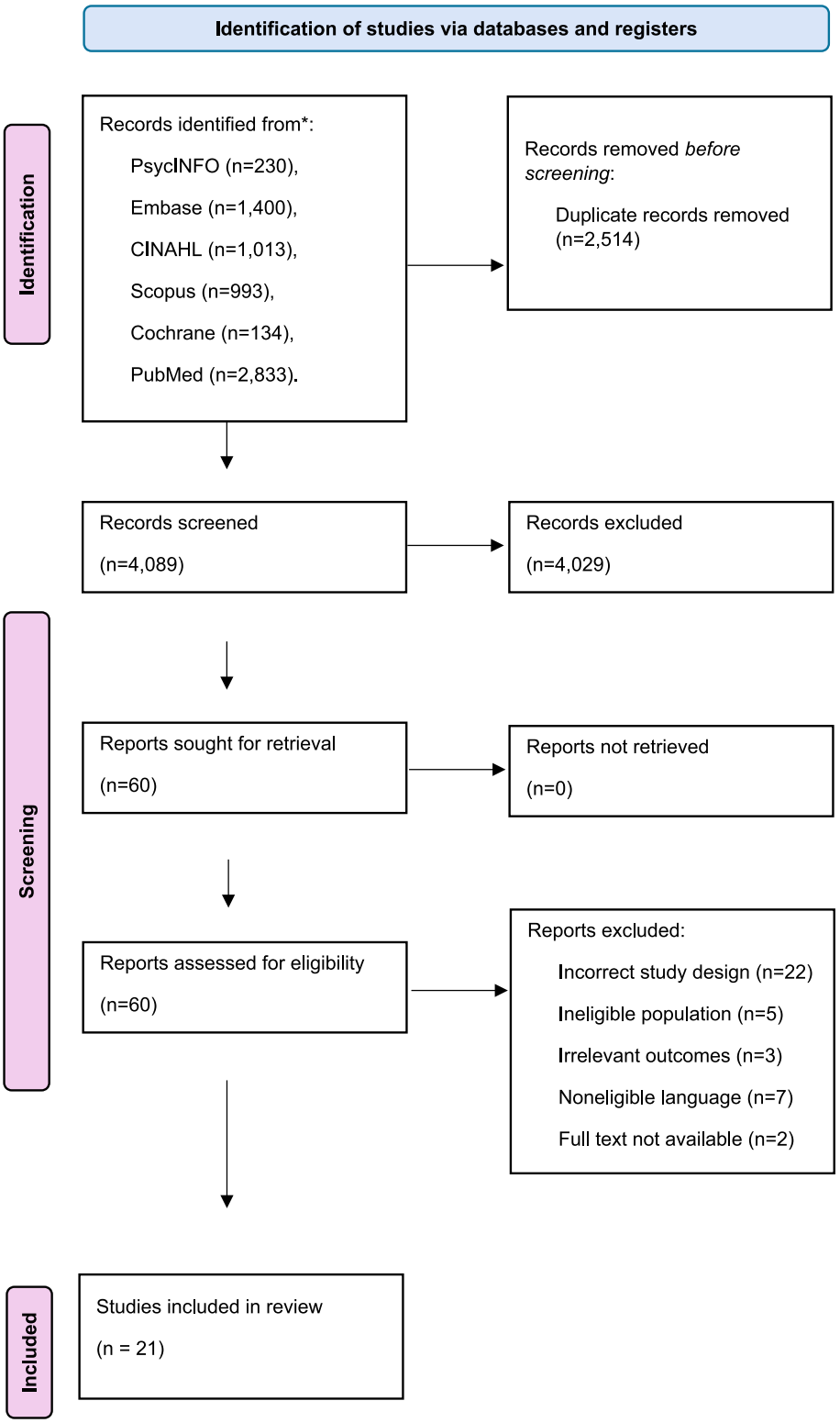


Fig. 1. PRISMA-ScR flow diagram of study selection.

clinical performance.

2.7. Data synthesis

Extracted data were synthesized narratively. Frequencies and cross-tabulations were generated to summarize intervention types, targeted competencies, and assessment instruments. A narrative synthesis was conducted to describe findings by intervention category and competency domain. To summarize the effects of the interventions, we applied vote counting based on the direction of effect (positive, null, or mixed), as recommended for heterogeneous evidence bases where meta-analysis is not feasible.

The results of vote counting were visualized through a harvest plot (Ogilvie et al., 2008)constructed in Microsoft Excel, which allows for an intuitive display of the distribution of studies, stratified by intervention type and competency domain. Each bar represented a single study, with height reflecting study size and shading indicating effect direction. Study design was coded through additional symbols, enabling simultaneous appraisal of effect patterns, methodological rigor, and evidence volume.

In addition, an evidence gap map (EGM) was developed using EPPI Mapper (White et al., 2020) and following established guidance (Saran et al., 2020; Snilstveit et al., 2016). The EGM was structured as a two-dimensional matrix, with intervention types (EPOC taxonomy) on the horizontal axis and competency domains (technical and non-technical skills) on the vertical axis. Cells were populated with markers denoting study volume and design. The EGM provides a structured overview of available evidence while highlighting domains requiring further primary research. Taken together, these approaches provide both an overview of intervention effectiveness (vote counting and harvest plot) and a visual identification of research gaps (evidence gap map).

2.8. Ethics and registration

As this review synthesized data from published sources, no ethics approval was required. The protocol was prospectively registered on the Open Science Framework (OSF [https://doi.org/10.17605/OSF.IO/ZSFJP]).

3. Results

3.1. Study selection

Database searches retrieved 6603 records and, after de-duplication, 4089 titles/abstracts were screened. Sixty full texts were assessed in detail, and 21 studies met the inclusion criteria and were included in this scoping review (Fig. 1).

3.2. Study characteristics

Table 1 summarizes the data extracted from the 21 included studies. Most of them were published between 2010 and 2025 and conducted across diverse regions, including Asia ($n = 12$; 57%; China, Iran, Japan, South Korea), North America ($n = 4$; 19%; Canada, United States), Europe ($n = 3$; 14%; Denmark, Germany, United Kingdom), Oceania (n = 1; 5%; Australia), and Africa (n = 1; 5% Nigeria). Study designs comprised single-group pre–post or self-controlled evaluations ($n = 11$; 53%), randomized controlled trials ($n = 7$; 33%), non-randomized comparative or controlled before–after studies (n = 3; 14%). Sample sizes ranged from 7 to 300 participants and involved scrub nurses, circulating nurses, labor and delivery nurses, and mixed OR nurse cohorts.

3.3. Intervention characteristics

The 21 included interventions targeted a wide spectrum of OR nursing competencies. Intervention types were categorized according to the Cochrane EPOC taxonomy (Practice & Care, 2016). The vast majority were educational interventions ($n = 19$; 90%), including: structured curricula (Aiyedun Lawal et al., 2025; Allanson & Fulbrook, 2010; Stucky et al., 2024; Zhang et al., 2021); non-virtual simulation programs (Bevil et al., 2020; Crocco et al., 2023; Hara et al., 2022; Skov et al., 2022; Whelan et al., 2018); immersive/VR formats (Clarke et al., 2020; Edwards et al., 2021; Ichihara et al., 2025; Khorammakan et al., 2024); blended or video-based training (Chen & Lian, 2024; Silab et al., 2024); workshops grounded in validated behavioral frameworks (CPLINTS/SPLINTS)(Kalantari et al., 2021; Mohammadi et al., 2025); targeted sterilization/irrigation training (Karami et al., 2017); and wearable-assisted, problem- and script-based learning (Zhao & Cong, 2019).

Only one intervention (5%) was behavioral, relying on environmental cues (poster-based electrosurgery reminders)(Fereidouni et al., 2022), and one (5%) was organizational, introducing a structured handoff tool (SWITCH) with accompanying education (Lee & Kim, 2024).

The length of interventions varied from brief 45-minute sessions (Hara et al., 2022; Karami et al., 2017) to extended curricula over several weeks or months (Edwards et al., 2021; Khorammakan et al., 2024; Stucky et al., 2024). Most programs incorporated structured debriefing, reflective exercises, or peer feedback, with follow-up assessments up to three months in some cases (Aiyedun Lawal et al., 2025; Bevil et al., 2020).

3.4. Competencies targeted

Competencies targeted by the interventions were classified into technical (procedural and task-related) and non-technical (cognitive, social, and affective) domains. Most studies ($n = 11$; 52%) addressed both, integrating procedural skill development with broader professional competencies such as self-efficacy, confidence, communication, or stress management (Aiyedun Lawal et al., 2025; Allanson & Fulbrook, 2010; Bevil et al., 2020; Edwards et al., 2021; Khorammakan et al., 2024; Lee & Kim, 2024; Skov et al., 2022; Stucky et al., 2024; Whelan et al., 2018; Zhang et al., 2021; Zhao & Cong, 2019). Seven studies (33%) focused exclusively on technical domains such as instrument recognition, electrosurgery safety, sterilization, patient positioning, or infection prophylaxis (Chen & Lian, 2024; Clarke et al., 2020; Fereidouni et al., 2022; Hara et al., 2022; Ichihara et al., 2025; Karami et al., 2017; Silab et al., 2024). Three interventions (15%) targeted non-technical domains only, addressing teamwork, communication, leadership, situational awareness, or nursing presence (Crocco et al., 2023; Kalantari et al., 2021; Mohammadi et al., 2025).

3.5. Instruments and outcome measures

Evaluation methods mapped across the 21 included studies combined objective performance measures, self-report questionnaires, observer ratings, and physiological indicators. Knowledge was assessed in seven studies (33%) using multiple-choice tests (Allanson & Fulbrook, 2010; Bevil et al., 2020; Karami et al., 2017), structured written assessments (Aiyedun Lawal et al., 2025; Stucky et al., 2024), or validated questionnaires such as the KAP survey (Chen & Lian, 2024; Zhang et al., 2021). Technical performance was evaluated in ten studies (48%) through structured checklists tailored to procedure-specific skills (Fereidouni et al., 2022; Karami et al., 2017; Silab et al., 2024; Zhang et al., 2021) or simulation-derived automated metrics including accuracy, time, error rates, and motion tracking (Clarke et al., 2020; Edwards et al., 2021; Hara et al., 2022; Ichihara et al., 2025; Khorammakan et al., 2024; Skov et al., 2022).

Non-technical competencies were explicitly assessed in three studies (14%) using validated instruments such as the CPLINTS checklist (Kalantari et al., 2021), SPLINTS-based self-efficacy scales (Mohammadi et al., 2025), and handoff-related tools including Rowe's Handoff

Table 1
Characteristics of included studies ($n = 21$).

Study (author, year, country)	Population (N, role)	Study design	Intervention (type, duration, features)	Competencies targeted	Instruments & outcome measures	Outcome measures	Evaluation method	Main results
Allanson & Fulbrook, 2010, Australia	49 novice/ mixed OR nurses	Pre–post single group	5-day structured curriculum (PIP): lectures, simulation, practice on perioperative basics	Technical + non-technical (knowledge, psychomotor skills, confidence)	MCQ test; self-assessment → knowledge, competence, confidence	Knowledge, competence, confidence	Objective test, self-report	Significant improvements in all outcomes; residual gaps in specific topics.
Bevil et al., 2020, USA	12 periop nurses	Pre–post with 1- and 3-mo follow-up	1.5-hour high-fidelity simulation + lecture: debriefing and follow-up	Technical + non-technical (knowledge, self-efficacy)	MCQ test; survey → knowledge retention, self-efficacy, satisfaction	Knowledge retention, self-efficacy, satisfaction	Objective test, self-report	Knowledge ↑ (52% → 90%, retained at 3 mo); improved self-efficacy and satisfaction.
Chen and Lian, 2024, China	173 OR nurses	Pre–post single group	Blended adult-learning program: e-learning, simulations, group discussion on infection prevention	Technical (infection prevention: knowledge, attitudes, practice)	Validated KAP questionnaire	Knowledge, attitudes, practice	Self-report (validated)	Significant improvements in all KAP domains ($p < 0.001$).
Clarke et al., 2020, Canada	89 periop nurses (49 exp, 40 control)	RCT	Tablet-based simulation (PeriopSim, 3 sessions): instrument recognition, speed/accuracy training	Technical (instrument recognition)	PeriopSim metrics; survey → accuracy, speed, retention, satisfaction	Accuracy, speed, retention, satisfaction	Simulation metrics, self-report	Simulation group faster, more accurate; effects retained at 7 days.
Crocco et al., 2023, USA	34 circulating nurses	Pre–post single group	1-hour education on nursing presence: discussion, simulation, debriefing	Non-technical (nursing presence)	Knowledge test; survey; behavioral checklist	Knowledge, perceptions, behaviors	Objective checklist, self-report	Increased knowledge and observed behaviors; perceptions unchanged (ceiling effect).
Edwards et al., 2021, UK	10 scrub nurses	Pre–post single group	Immersive VR curriculum (4 sessions/4 weeks): rTKA scrub training with transfer assessment	Technical + non-technical (operative tasks, confidence, anxiety)	VR metrics; peer assessment; survey	Errors, operative time, transfer, confidence, anxiety	Simulation metrics, observer rating, self-report	Errors/time ↓; skills transfer ↑ (11% → 84% correct); confidence ↑, anxiety ↓.
Fereidouni et al., 2022, Iran	100 OR nurses	Pre–post quasi-experimental	1-month poster-based reminders: electrosurgery safety reinforcement	Technical (electrosurgery safety)	ESU checklist	Electrosurgery safety performance	Objective checklist	Safety performance improved; no effect where equipment limited.
Hara et al., 2022, Japan	30 novice OR nurses	Longitudinal pre–post	3 × 45-min scrub nurse simulations: specialty scenarios with reflection	Technical (scrub duties)	Questionnaire + reflections	Visualization, application of duties	Self-report, reflective	Improved visualization and application of duties; mental imagery highlighted.
Ichihara et al., 2025, Japan	13 scrub nurses	Non-randomized comparative	VR headset training vs manual practice (several sessions): visualization, handling, error reduction	Technical (visualization, handling, errors)	Self−/peer-assessment; error counts	Understanding, visualization, errors	Observer rating, self-report	VR > manual for visualization/ understanding; peer ratings ns; some motion sickness.
Kalantari et al., 2021, Iran	300 circulating nurses (150/ 150)	Controlled before–after	2-hour NTS workshop (CPLINTS): teamwork, communication, leadership	Non-technical (teamwork, communication, leadership)	CPLINTS checklist	Teamwork, communication, leadership	Observer rating (validated)	Significant gains in all NTS domains; greater in younger/less experienced nurses.
Karami et al., 2017, Iran	61 OR personnel	Pre–post single group	Sterilization/ irrigation training (3 × 45-min + booklet)	Technical (sterilization, irrigation)	MCQ; skills checklist	Knowledge, performance	Objective test, checklist	Knowledge and performance improved significantly;

(*continued on next page*)

Table 1 (*continued*)

Study (author, year, country)	Population (N, role)	Study design	Intervention (type, duration, features)	Competencies targeted	Instruments & outcome measures	Outcome measures	Evaluation method	Main results
								retraining recommended.
Khorammakan et al., 2024, Iran	72 scrub nurses (36/36)	RCT	VR scrub training (4 weeks): self-efficacy and performance assessment	Technical + non-technical (performance, self-efficacy)	Self-efficacy tool; performance tool	Self-efficacy, performance	Self-report, objective	Significant improvements in self-efficacy and performance ($p < 0.001$).
Aiyedun Lawal et al., 2025, Nigeria	26 periop nurses	Pre–post pilot with 3-mo follow-up	5-day structured curriculum (NCSL cleft care): lectures, simulation, clinical skills	Technical + non-technical (knowledge, satisfaction, dissemination)	Knowledge test; survey	Knowledge, satisfaction, dissemination	Objective test, self-report	Knowledge ↑; high satisfaction; 40% delivered training at 3 mo.
Lee & Kim, 2024, South Korea	80 OR nurses (40/40)	RCT (nonequivalent groups)	Structured handoff tool (SWITCH, 2 sessions)	Non-technical + technical (handoff quality, self-efficacy)	Handoff scales (satisfaction, performance, GICC)	Handoff satisfaction, performance, comm competence	Self-report (validated), observer rating	Improved satisfaction, self-efficacy, performance; no change in communication competence.
Mohammadi et al., 2025, Iran	60 scrub practitioners (54 analyzed)	Single-blind RCT	NTS training (2 × 2-hour SPLINTS-based sessions)	Non-technical (awareness, teamwork, task management)	SPLINTS-based questionnaire	Awareness, teamwork, task management	Self-report (validated)	Improved self-efficacy overall; task management ns.
Silab et al., 2024, Iran	62 OR nurses	Parallel-group RCT	1-month video-based training (mobile app): patient positioning standards	Technical (patient positioning)	Positioning checklist	Adherence to positioning standards	Observer rating (validated)	VBT group significantly improved adherence; replication suggested.
Skov et al., 2022, Denmark	7 endovascular scrub nurses	Self-controlled pre–post	2-Step simulation program (ANGIO Mentor EVAR)	Technical + non-technical (errors, stress, communication)	Error tool; HRV	Errors, stress, comms, time	Objective error/time, physiological HRV	Errors ↓ 51%, stress ↓, comm ↑; time trend ↓.
Stucky et al., 2024, Germany/US	17 labor & delivery nurses	Pre–post single group	Standardized curriculum (periop 101, ~3 months): 25 e-learning modules, practicum	Technical + non-technical (knowledge, periop competence)	Knowledge test; PPCS-R	Knowledge, competence	Objective test, self-report	Significant improvements across competence domains; reduced variation.
Whelan et al., 2018, Canada	46 new periop nurses	Pre–post evaluation	Simulation-based labs (~80 h): multispecialty training + debriefing	Technical + non-technical (preparedness, satisfaction)	Survey	Preparedness, satisfaction	Self-report	Preparedness ↑ (3.9 → 4.4/5); 86% satisfied.
Zhang et al., 2021, China	41 OR nurses (pre-job)	RCT	Hierarchical teaching with monthly simulations	Technical + non-technical (skills, ability, satisfaction)	Knowledge/skills tests; survey	OR skills, ability, satisfaction	Objective tests, self-report	Intervention group improved in all outcomes.
Zhao & Cong, 2019, China	$N = 20$ novice OR nurses	RCT	Wearable tech + problem-scripted learning: Google Glass–enhanced training	Technical + non-technical (performance, preparedness, satisfaction)	Survey	Preparedness, performance, satisfaction	Self-report	Intervention group scored higher across outcomes; satisfaction improved.

Legend. RCT = randomized controlled trial; OR = operating room; L&D = labor and delivery; ESU = electrosurgical unit; EVAR = endovascular aneurysm repair; VR = virtual reality; iVR = immersive virtual reality; NTS = non-technical skills; HRV = heart rate variability; PPCS-R = Perioperative Competence Scale – Revised; KAP = knowledge, attitude, practice; PSBL = problem- and script-based learning; ns = non-significant; ↑ = increase; ↓ = decrease.

Satisfaction Scale, the Hand-off Self-Efficacy instrument, and the Global Interpersonal Communication Competence scale (Lee & Kim, 2024). Broader OR nursing competence was captured in up to three studies (14%), most robustly with the Perceived Perioperative Competence Scale–Revised (PPCS-R) (Stucky et al., 2024).

Additional self-reported outcomes such as confidence, preparedness, satisfaction, anxiety, and perceived behaviors were reported in six studies (29%) (Aiyedun Lawal et al., 2025; Bevil et al., 2020; Crocco et al., 2023; Edwards et al., 2021; Whelan et al., 2018; Zhao & Cong, 2019). Two studies (10%) applied innovative evaluation strategies, including physiological stress via heart rate variability (HRV) (Skov et al., 2022) and peer surgeon assessment of scrub nurse performance (Ichihara et al., 2025). While some instruments demonstrated robust psychometric validation (e.g., Chen & Lian's KAP tool, Silab's positioning checklist, Lee & Kim's handoff instruments, Mohammadi's SPLINTS-derived scale, Stucky's PPCS-R), many study-developed checklists and surveys lacked formal validation, limiting comparability across studies.

3.6. Vote counting and harvest plots

By intervention type, most studies evaluated educational strategies ($n = 19$), of which ($n = 16$; 84.2%) reported positive effects and ($n = 3$; 15.8%) mixed effects; none reported null results. Behavioral

interventions were rare (n = 1) and showed a positive result (n = 1; 100%). One organizational intervention was identified and yielded mixed effects (n = 1; 100%). These findings are illustrated in the harvest plot (Fig. 2a) and summarized in the vote-counting table (Table 2).

By competency domain, 11 studies addressed both technical and non-technical skills, with (n = 10; 90.9%) positive and (n = 1;9.1%) mixed. Seven studies focused exclusively on technical skills, with (n = 6; 85.7%) positive and (n = 1; 14.3%) mixed. Three studies targeted non-technical skills alone, with (n = 1; 33.3%) positive and (n = 2; 66.7%) mixed. No study reported null effects. The corresponding harvest plot (Fig. 2b) and vote-counting table (Table 2) provide a visual and numerical synthesis of these patterns.

Table 2
Vote counting of intervention types and competency domains by direction of effect.

Dimension	Category	Positive, n (%)	Mixed, n (%)	Null, n (%)	Total, n (%)
Intervention type	Educational	16 (84.2)	3 (15.8)	0 (0)	19 (100)
	Behavioral	1 (100)	0 (0)	0 (0)	1 (100)
	Organizational	0 (0)	1 (100)	0 (0)	1 (100)
Competency domain	Technical	6 (85.7)	1 (14.3)	0 (0)	7 (100)
	Non-technical	1 (33.3)	2 (66.7)	0 (0)	3 (100)
	Both	10 (90.9)	1 (9.1)	0 (0)	11 (100)

3.7. Evidence gap map

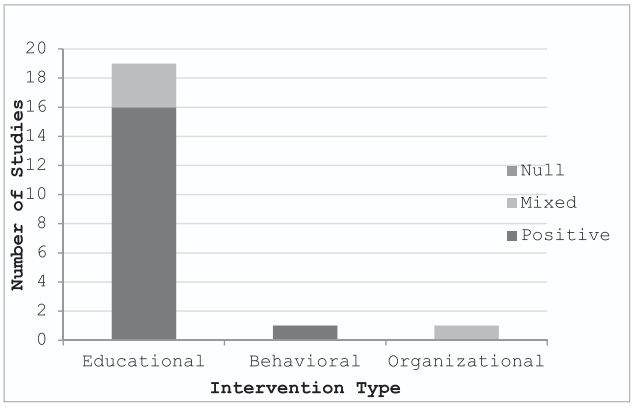
A total of 21 unique studies (32 coded entries) were mapped in the evidence gap map (Fig. 3). Rows represent the competency focus (technical vs non-technical), while columns correspond to intervention subtypes (e.g., structured curricula, simulation with or without VR, blended/e-learning, video-based training, workshops on non-technical skills, and organizational or behavioral interventions). Bubble size indicates the number of studies, and shading reflects study design (lighter tones for pre–post studies, darker tones for RCTs, CBAs, and other comparative designs). The map shows a concentration of evidence for simulation-based interventions (both VR and non-VR) and structured curricula, with studies addressing both technical and non-technical competencies. Evidence on behavioral and organizational strategies was scarce, with only one study each. Most studies were pre–post designs, while RCTs and other comparative approaches were less frequent. Notably, gaps remain for certain combinations, such as video-based training for non-technical skills, where no studies were identified.

4. Discussion

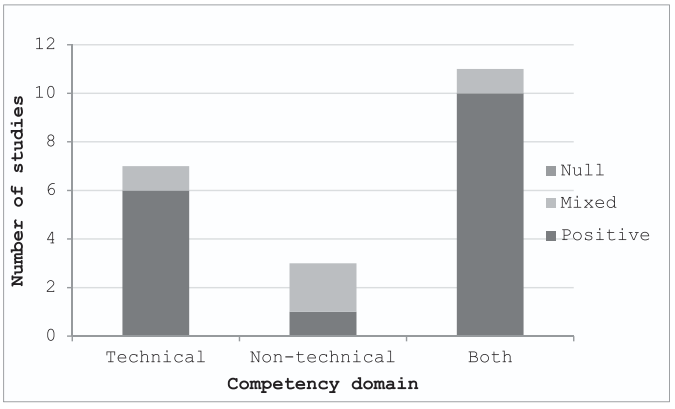
The aim of this scoping review and evidence gap mapping was to systematically identify, categorize, and synthesize interventions designed to improve the technical and non-technical competencies of OR nurses, and to highlight areas where evidence remains limited. To our knowledge, this is the first review in OR nursing to combine traditional scoping methodology with vote-counting, harvest plots, and evidence gap mapping to provide both narrative and visual synthesis of the available evidence. Twenty-one studies were identified, most of which evaluated educational interventions, particularly simulation-based training and structured curricula, with consistently positive effects on knowledge, self-efficacy, preparedness, and procedural performance. A smaller number of studies addressed non-technical competencies such as teamwork, leadership, or communication, with promising but less consistent results. Organizational and behavioral interventions, such as structured handoff tools or environmental reminders, were rarely studied, highlighting a narrow focus of current research. Overall, the evidence base remains heterogeneous with respect to study design, intervention duration, measurement tools, and outcomes.

Previous reviews have either focused exclusively on non-technical skills or explored mixed professional populations, limiting their applicability to OR nurses. Our review extends this evidence by mapping both technical and non-technical domains, and by distinguishing intervention subtypes using the EPOC taxonomy. Consistent with (Gillespie et al., 2018) and (Uçak & Cebeci, 2021), our findings confirm that OR nursing competence is conceptualized inconsistently across studies, which complicates comparisons and meta-analyses. Although competencies were categorized as technical and non-technical skills in this review, the boundary between these domains is not always clear-cut. Non-technical skills such as communication, teamwork, and decision-making can directly influence the execution of technical procedures, suggesting that these competencies should be considered interrelated rather than strictly separate constructs. The evidence gap map revealed substantial gaps in studies addressing non-technical skills, long-term retention of competencies, cost-effectiveness, and organizational innovations. Few randomized controlled trials were identified, and follow-ups beyond three months were uncommon.

The predominance of educational interventions identified in this review aligns with wider trends in health professions education, where simulation-based training and structured curricula are increasingly recognized as effective strategies for bridging the gap between theory



a)



b)

Fig. 2. Harvest plots of intervention types and competency domains by direction of effects.
Notes. Combined harvest plots summarizing the direction of effects across included studies. The left panel (a) displays intervention types (Educational, Behavioral, Organizational, Educational + Behavioral), and the right panel (b) displays competency domains (Technical, Non-technical, Both). Bars represent the number of studies in each category, with shading indicating whether outcomes were positive, mixed, or null. No studies reported null effects.

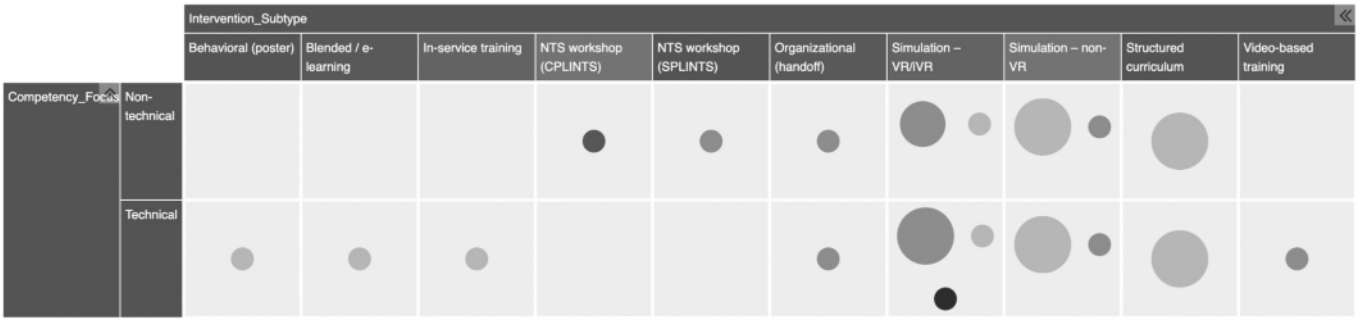


Fig. 3. Evidence gap map of interventions for OR nursing competencies.
Legend. Rows represent competency focus (technical vs. non-technical), and columns represent intervention subtypes. Bubble size corresponds to the number of studies. Shading indicates study design: light grey = pre–post; medium grey = controlled before–after (CBA); dark grey = randomized controlled trial (RCT); black = other comparative designs.

and practice (Daneshfar & Moonaghi, 2025). In medical education, simulation has consistently been shown to improve both procedural and soft skills when compared with traditional lecture-based methods (Elendu et al., 2024). High-fidelity simulation environments are particularly valued for offering a safe and controlled space in which learners can rehearse technical tasks, practice error recovery, and strengthen teamwork without risk to patients (Park et al., 2025). The concentration of evidence for simulation-based interventions in OR nursing therefore mirrors developments in other clinical disciplines and reinforces its role as a cornerstone of contemporary professional education. However, the predominance of educational interventions also reflects a broader limitation in health professions education research. Many studies primarily demonstrate improvements in knowledge, confidence, or procedural performance following training, which are expected outcomes when education is delivered. Future research should therefore prioritize comparative designs to identify which educational approaches are most effective and efficient, and should include outcomes beyond learner-level measures, such as patient safety, team performance, and staff-related outcomes.

Despite this consistency, the limited emphasis on non-technical skills in the studies included in our review contrasts with the broader literature, which highlights teamwork, leadership, and communication as essential elements of safe surgical care. Evidence from surgery and anesthesiology shows that adverse events in the OR are more frequently associated with failures in communication and situational awareness than with deficiencies in technical performance (Andereggen et al., 2022). Similarly, training programs focused on non-technical skills in critical care settings have demonstrated improvements in communication and situational awareness, though their impact on wider organizational outcomes such as safety culture remains inconsistent (Pimenta et al., 2025). These findings suggest that while the importance of non-technical competencies is widely acknowledged, perioperative nursing education has yet to fully integrate them in a systematic and evidence-based way (Ounounou et al., 2019). This imbalance may reinforce a narrow view of competence development as an individual educational issue, potentially overlooking the influence of teamwork, safety culture, and organizational conditions in the OR.

The underrepresentation of organizational and behavioral interventions in our review reflects a broader gap in implementation science and health systems research. In other healthcare contexts, structured communication tools, environmental cues, leadership engagement, and workflow redesigns have been associated with measurable improvements in patient safety and professional performance (Zenati et al., 2022). However, robust evaluations of such strategies remain scarce, and the perioperative nursing literature is no exception. Recent nursing studies exploring multimodal organizational and behavioral approaches—such as combining leadership training with environmental modifications or team engagement—highlight both the promise of these strategies and the methodological challenges of capturing their impact (Alsadaan et al., 2023; Lenssen et al., 2025).

Finally, the heterogeneity of outcome measures used in the included studies mirrors challenges seen in other domains of medical and nursing education. While validated frameworks offer structured approaches for evaluating perioperative skills, their uptake remains inconsistent. Many studies continue to rely on study-specific checklists or unvalidated surveys, which hampers comparability across interventions and limits the accumulation of high-quality evidence (Dawod et al., 2024; Xie et al., 2024). A consensus on standardized, psychometrically robust outcome measures would not only strengthen research rigor but also facilitate benchmarking across institutions and countries.

Future research should prioritize rigorous, comparative designs, integration of validated measurement tools, and exploration of outcomes that extend to patient safety, teamwork effectiveness, and system efficiency.

4.1. *Implications for practice, education, and research*

The evidence supports the integration of structured simulation, blended learning, and standardized curricula into continuing education for OR nurses. However, the scarcity of organizational and policy-level interventions suggests that nurse managers and policymakers have underutilized strategies that go beyond individual skill acquisition. The limited use of validated instruments also hampers benchmarking across institutions, underscoring the need for consensus on competence assessment tools such as the PPCS-R or validated NTS checklists. For research, future studies should prioritize multicenter trials with long-term follow-up and employ rigorous comparative designs, such as randomized controlled trials. The consistent use of validated outcome measures will be essential to generate robust and comparable evidence on interventions for OR nurses' technical and non-technical skills.

4.2. *Strengths and limitations*

This review has several strengths, including adherence to established scoping methodologies, a comprehensive search across four major databases, duplicate screening and data extraction, and the use of visual synthesis techniques. However, some limitations must be acknowledged. Restricting eligibility to English and Italian literature, may have introduced language bias, and the exclusion of qualitative studies and quality improvement projects, which may have omitted deeper insights into contextual and experiential aspects of competence development.

5. Conclusion

In conclusion, this scoping review demonstrates that the evidence base for OR nursing competency development is dominated by

educational and simulation-based interventions, while behavioral and organizational strategies remain underexplored. Interventions frequently target both technical and non-technical skills, yet rigorous evaluation of non-technical domains is limited. Addressing these gaps is critical to building a comprehensive, evidence-informed framework for OR nursing workforce development and strengthen the safety and quality of perioperative care.

Ethics and registration

As this review synthesized data from published sources, no ethics approval was required. The protocol was prospectively registered on the Open Science Framework (OSF) [https://doi.org/10.17605/OSF.IO/ZSFJP].

CRediT authorship contribution statement

Laura Rasero: Writing – review & editing, Supervision, Resources, Methodology, Investigation, Conceptualization. **Camilla Elena Magi:** Writing – original draft, Methodology, Formal analysis, Data curation. **Paolo Iovino:** Writing – original draft, Investigation, Data curation, Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Maria Fatima Cappelletti:** Writing – original draft, Resources, Investigation. **Angela Durante:** Writing – original draft, Resources, Data curation. **Angela Durante:** Writing – original draft, Resources, Data curation. **Patrizia de Angeli:** Writing – original draft, Investigation, Data curation. **Benedetta Natali:** Writing – original draft, Investigation, Data curation. **Francesco Cichero:** Writing – original draft, Investigation, Data curation. **Paolo Gori:** Writing – original draft, Investigation, Data curation. **Laura Lumachi:** Writing – original draft, Investigation, Data curation. **Cinzia Pallari:** Writing – original draft, Investigation, Data curation. **Giuliana Pizza:** Writing – original draft, Investigation, Data curation. **Marilise Ibba:** Writing – original draft, Investigation, Data curation. **Guido Spessot:** Writing – original draft, Investigation, Data curation. **Stefano Bambi:** Writing – review & editing, Supervision, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Detailed search strategy

Database	Search string
PubMed	(("Perioperative Nursing"[MeSH] OR "Operating Room Nurses"[MeSH] OR "operating room nurse*" OR "perioperative nurse*" OR "scrub nurse*" OR "circulating nurse*" OR "surgical nurse*" OR "surgical theatre nurse*") AND ("Clinical Competence"[MeSH] OR competenc* OR skill* OR performance* OR capability OR "technical skills" OR "non-technical skills" OR "hard skills" OR "soft skills") AND ("Education, Nursing, Continuing"[MeSH] OR education OR training OR simulation OR mentoring OR "professional development" OR "educational intervention" OR intervention* OR "simulation-based education" OR coaching OR supervision OR "organizational innovation" OR "quality improvement" OR "AI-based training") AND (effectiveness OR outcome* OR impact OR evaluation OR "learning outcome*"))
CINAHL	(MH "Perioperative Nursing" OR "operating room nurse*" OR "perioperative nurse*" OR "scrub nurse*" OR "surgical nurse*" OR "surgical theatre nurse*") AND (MH "Clinical Competence" OR competenc* OR skill* OR performance* OR capability OR "technical skills" OR "non-technical skills") AND (MH "Education, Continuing" OR education OR training OR simulation OR mentoring OR "professional development" OR intervention* OR "simulation-based education" OR coaching OR supervision OR "quality improvement") AND (effectiveness OR outcome* OR impact OR evaluation OR "learning outcome*")
Scopus	TITLE-ABS-KEY("operating room nurse*" OR "perioperative nurse*" OR "scrub nurse*" OR "surgical nurse*" OR "surgical theatre nurse*") AND TITLE-ABS-KEY("clinical competence" OR competenc* OR skill* OR performance* OR capability OR "technical skills" OR "non-technical skills") AND TITLE-ABS-KEY(education OR training OR simulation OR mentoring OR "professional development" OR intervention* OR "simulation-based education" OR coaching OR supervision OR "quality improvement" OR "AI-based training") AND TITLE-ABS-KEY(effectiveness OR outcome* OR impact OR evaluation OR "learning outcome*")
Embase	('perioperative nursing'/exp OR 'operating room nurse*' OR 'perioperative nurse*' OR 'scrub nurse*' OR 'surgical nurse*' OR 'surgical theatre nurse*') AND ('clinical competence'/exp OR competenc* OR skill* OR performance* OR capability OR 'technical skills' OR 'non-technical skills') AND ('continuing education'/exp OR education OR training OR simulation OR mentoring OR 'professional development' OR intervention* OR 'simulation-based education' OR coaching OR supervision OR 'quality improvement' OR 'AI-based training') AND (effectiveness OR outcome* OR impact OR evaluation OR 'learning outcome*')

Note. MeSH = Medical Subject Headings (PubMed); MH = CINAHL Headings; exp = Emtree explosion term (Embase). Search strategies were adapted to the indexing systems and operators of each database. Truncation (*) was used to capture variations of root terms. Searches were limited to English and Italian language publications, with no date restrictions.

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