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Optimizing Non-Technical Skill Transfer in Advanced Trauma Resuscitation An Integrative Review and Systems Framework

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Research Article

Keywords: Non-technical skills, Trauma resuscitation, Simulation-based education, Implementation science, European Trauma Course, Patient safety

Posted Date: August 26th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10618642/v1

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Abstract

Purpose

Safe trauma resuscitation depends heavily on non-technical skills (NTS) such as leadership, communication, situation awareness, and decision-making. While simulation-based education is the primary modality for teaching these competencies, the extent to which laboratory proficiency translates into sustained clinical practice remains poorly defined. This review aims to evaluate the empirical evidence on simulation-based NTS training in multidisciplinary trauma teams and propose a framework to guide skill transfer.

Methods

An integrative review was conducted following the Whittemore and Knafl framework and PRISMA 2020 guidelines. Systematic searches of PubMed (including MEDLINE), Scopus, and Web of Science identified empirical studies published between January 2010 and May 2026 evaluating simulation-based NTS training in trauma teams. Studies were critically appraised and synthesized using thematic analysis.

Results

Forty-four studies met the inclusion criteria. Simulation training consistently produces immediate improvements in teamwork, leadership, and participant confidence. However, evidence demonstrating retention of these skills beyond six months or direct translation into measurable patient-centered outcomes is limited. Skill transfer is heavily influenced by individual factors (e.g., baseline clinical experience), pedagogical design (e.g., debriefing structure), and organizational readiness. Studies indicate that NTS-focused debriefing is associated with significantly greater improvements compared to technical-only debriefing.

Conclusions

The translation of simulation training into enhanced clinical performance is not automatic; it is a complex process mediated by individual, pedagogical, and systemic factors. We introduce the Simulation-to-Performance Transfer Framework (SPTF) to conceptualize these interacting variables, providing a structured approach for educators and institutional leaders to optimize the clinical impact of trauma simulation programs.

1. INTRODUCTION

1.1. Trauma Care as a Complex Sociotechnical System

Trauma resuscitation represents one of the most time-critical and cognitively demanding environments in acute healthcare. Despite significant advances in damage-control resuscitation and surgical techniques, traumatic injury remains a leading global cause of mortality and long-term morbidity, disproportionately affecting the young and economically active demographic [1]. The World Health Organization estimates that over four million deaths annually are attributable to injuries, and trauma is the leading cause of death in individuals under the age of 45 in high-income countries [1]. Systemic audits and root-cause analyses of major trauma care frequently

reveal that adverse events and preventable errors are less often attributable to deficiencies in technical or procedural skills, and more commonly linked to breakdowns in communication, ambiguous leadership, and inadequate interprofessional coordination [2].

Trauma resuscitation functions as a complex sociotechnical system [3]. The cognitive load, procedural intensity, and coordination requirements of major trauma exceed the capacity of any single clinician. Consequently, the quality of care is determined by the collective performance of the multidisciplinary team interacting within a specific physical and cultural environment [4]. Optimized team dynamics correlate with reduced time to critical interventions, such as hemorrhage control, definitive imaging, or operative decision-making. However, the precise mechanisms by which team-level behaviors influence long-term patient outcomes, including survival, functional recovery, and length of hospital stay, require further elucidation [5]. Understanding these mechanisms is essential for designing educational interventions that are not merely satisfying to participants but genuinely protective for patients.

1.2. The Role of Non-Technical Skills in Trauma Resuscitation

Non-technical skills (NTS) encompass the cognitive, social, and personal-resource competencies that complement technical expertise. These skills are fundamental to maintaining safe performance under acute physiological and temporal stress [3]. Within the trauma setting, four primary behavioral domains are consistently identified as critical to effective team function.

Leadership refers to the ability to direct, coordinate, and support a multidisciplinary team under pressure [6]. Effective trauma leadership requires structuring the physical environment, explicitly assigning roles, continuously monitoring team performance, and fostering psychological safety. Competent leaders adapt their command style dynamically, transitioning between directive and participative approaches based on clinical complexity and team composition [6]. In the chaotic initial minutes of a major trauma resuscitation, the absence of clear leadership frequently results in duplicated efforts, missed injuries, and delayed definitive care.

Communication and teamwork constitute the operational mechanisms of team function [7]. This domain includes closed-loop communication (explicit directives followed by confirmation of execution), systematic task allocation, and the capacity for respectful assertion across traditional hierarchical boundaries. Communication failures are frequently cited as primary contributors to preventable adverse events in emergency settings [7]. Effective communication is not merely about the volume of information exchanged but about its precision, timing, and relevance to the clinical situation.

Situation awareness describes the continuous cognitive process of perceiving clinical data, comprehending its immediate significance, and projecting the patient's near-term physiological trajectory [8]. This is maintained through a shared mental model among team members regarding the patient's status, pending interventions, and available resources. When situation awareness degrades, clinicians may fixate on a single problem while failing to recognize evolving threats elsewhere, a phenomenon well-documented in aviation and increasingly recognized in acute medicine.

Decision-making encompasses the ability to formulate working diagnoses and execute management plans under conditions of uncertainty, incomplete information, and severe time constraints [9]. This requires balancing cognitive processing speed with clinical accuracy while remaining adaptive to evolving physiological

parameters. In trauma, decisions are rarely made in isolation; they emerge from the interaction between individual clinical judgment and the collective intelligence of the team.

1.3. Simulation-Based Education in Trauma

Simulation has emerged as the standard methodology for teaching and assessing NTS [10]. It provides a controlled, psychologically safe environment where multidisciplinary teams can rehearse complex, high-acuity scenarios without exposing actual patients to risk [10]. The underlying pedagogical principles rely on experiential learning [11], deliberate practice aimed at automating team coordination [12], and structured, reflective debriefing [13, 14]. The appeal of simulation is intuitive: it allows teams to practice rare, high-stakes events repeatedly, to make errors without consequence, and to receive immediate formative feedback.

Current literature consistently demonstrates that simulation programs generate significant, immediate improvements in teamwork metrics and participant confidence [2, 15]. However, the longitudinal impact of these interventions remains less clear. Trauma simulation requires substantial financial and logistical resources, including dedicated physical space, high-fidelity mannequins, trained facilitators, and the withdrawal of clinical staff from active patient care [16]. Furthermore, the efficacy of the training appears heterogeneous; baseline clinical experience and practitioner age influence learning outcomes, with less experienced clinicians often demonstrating attenuated gains in situation awareness and complex decision-making. This variability suggests that uniform, standardized courses may be less effective than tailored educational interventions adapted to the specific developmental stage of the learner [16].

1.4. The European Trauma Course Model

The European Trauma Course (ETC), administered under the auspices of the European Resuscitation Council, exemplifies contemporary team-focused trauma education [17]. In contrast to curricula centered primarily on individual clinical knowledge, such as Advanced Trauma Life Support (ATLS), the ETC integrates teamwork, leadership, and NTS equally with technical clinical management. This is achieved through multidisciplinary participation and formative, scenario-based team assessments [18]. The course explicitly teaches a horizontal team structure, where leadership is shared and communication is expected to flow freely across professional boundaries.

While the immediate educational benefits of the ETC are documented, evidence regarding sustained clinical translation is mixed. A national implementation study conducted in Portugal indicated that while 94% of participants reported a conceptual shift in their approach to trauma care, only 71.4% identified a durable alteration in their actual clinical behavior [19]. This discrepancy highlights the core challenge of simulation-based training: the gap between acquired knowledge and sustained behavioral implementation. The question is not whether simulation can teach NTS, but whether the skills learned in the laboratory survive contact with the operational realities of clinical practice.

1.5. Aim of the Review

Despite the widespread adoption of simulation-based training, critical questions persist regarding the predictive validity of current NTS assessment tools, the longitudinal retention of acquired skills, and the demonstrable impact on clinical morbidity and error rates [2, 5]. Furthermore, recent data suggest that poorly structured simulation, specifically scenarios lacking explicit NTS debriefing, may inadvertently degrade participants' pre-existing behavioral competencies [20].

This review aims to critically evaluate the empirical evidence concerning simulation-based NTS training in multidisciplinary trauma teams. Specifically, it seeks to identify the individual, pedagogical, and organizational mediators that influence the transfer of simulated performance to clinical practice. Based on this synthesis, we propose a conceptual framework designed to assist educators and healthcare administrators in optimizing the clinical translation of simulation investments.

2. METHODS

2.1. Study Design

An interpretive synthesis approach was utilized [22]. This methodology permits the integration of randomized controlled trials, quasi-experimental designs, and qualitative or mixed-methods research, facilitating a comprehensive analysis of complex interventions where outcomes are influenced by interacting individual and systemic factors [22]. The review was structured according to the Whittemore and Knafl five-stage framework: problem identification, literature search, data evaluation, data analysis, and presentation [23]. Reporting aligns with the PRISMA 2020 statement [24].

2.2. Search Strategy

A systematic search was executed across three electronic databases (PubMed/MEDLINE, Scopus, and Web of Science) for literature published between January 2010 and May 2026. The search strategy utilized combinations of Medical Subject Headings (MeSH) and keywords structured around three primary concepts: simulation ("simulation" OR "high-fidelity simulation" OR "in situ simulation" OR "simulation-based training"), trauma ("trauma" OR "trauma resuscitation" OR "trauma team" OR "trauma care"), and non-technical skills ("non-technical skills" OR "teamwork" OR "leadership" OR "communication" OR "situation awareness" OR "decision-making" OR "crisis resource management"). The database search was supplemented by backward and forward citation tracking of included articles. The search was restricted to peer-reviewed publications in the English language.

2.3. Eligibility Criteria

Inclusion criteria comprised: empirical original studies (randomized controlled trials, quasi-experimental designs, prospective evaluations, qualitative, or mixed-methods studies); interventions utilizing simulation-based education focused on non-technical skills in multidisciplinary trauma teams or relevant operational subgroups; studies reporting defined behavioral, educational, clinical, or organizational outcomes related to NTS or collective team performance; and articles published in peer-reviewed journals.

Exclusion criteria comprised: non-empirical publications (narrative reviews, editorials, opinion pieces); studies evaluating technical or surgical skills exclusively, without assessment of behavioral team dynamics; simulation training outside the context of acute trauma resuscitation (e.g., elective surgical training, prehospital care without hospital team involvement); and studies lacking a defined framework for evaluating non-technical skills.

2.4. Study Selection Process

Citations were imported into reference management software, and duplicates were removed. Two independent reviewers screened titles and abstracts against the eligibility criteria. Articles meeting the criteria, or those with insufficient information in the abstract to warrant exclusion, underwent full-text review by both independent

reviewers. Discrepancies were resolved through consensus discussion. The selection process is illustrated in the PRISMA flow diagram as shown in Fig. 1.

2.5. Data Extraction and Critical Appraisal

Data were extracted using a standardized, pilot-tested form, capturing: study characteristics (author, year, country, design, clinical setting, sample size); intervention details (simulation fidelity, duration, scenario type, debriefing methodology); outcome measures (specific NTS domains assessed, measurement instruments, quantitative/qualitative results); and implementation context (organizational barriers, facilitators, skill retention, patient-centered outcomes).

Critical appraisal focused on the distinction between immediate educational effects and longitudinal retention, the psychometric validity of the assessment tools utilized, methodological rigor (design, sample size, control groups), and the clinical relevance of the reported behavioral transfer. Studies were not excluded on the basis of quality, as the integrative methodology permits the inclusion of diverse designs to capture the full complexity of the intervention landscape.

2.6. Data Synthesis

Due to significant heterogeneity in study designs, intervention modalities, and outcome metrics, a quantitative meta-analysis was not feasible. Data were synthesized using a qualitative thematic approach [22]. Extracted data were iteratively coded across core behavioral domains, with specific attention directed toward the validity of assessment instruments and the structural or individual variables modifying the translation of simulated proficiency to clinical performance.

3. RESULTS

3.1. Methodological Profile of Included Studies

Forty-four studies met the inclusion criteria following the screening process (Fig. 1). The full characteristics of included studies are presented in Table 1. Analysis of the methodological architecture of these studies reveals specific limitations regarding the generalizability of the findings. Only 13.6% (n = 6) of the included articles utilized randomized controlled trial designs. The literature is predominantly composed of observational, cross-sectional, qualitative, and tool-validation designs (59.1%, n = 26), alongside pre/post-test evaluations (18.2%, n = 8) and quasi-experimental studies (9.1%, n = 4). Furthermore, 72.7% (n = 32) of the studies were conducted at single centers, with multi-site collaborations comprising only 6.8% (n = 3). More than one-third of the corpus (36.4%, n = 16) reported sample sizes of fewer than 50 participants. The majority of these studies reported statistically significant post-intervention improvements in NTS.

However, the combination of small sample sizes, monocentric settings, and potential publication bias necessitates cautious interpretation of the reported effect sizes. It is worth noting that the predominance of single-center studies reflects the logistical difficulty of organizing multidisciplinary trauma simulation across multiple institutions, rather than a failure of research ambition. The geographic distribution was weighted toward Northern Europe, North America, and Australasia, with limited representation from low- and middle-income settings where trauma burden is disproportionately high.

Table 1
Characteristics of included studies (full list of 44 studies)

Note: RCT = Randomized Controlled Trial; CRM = Crisis Resource Management; SA = Situation Awareness; TEAM = Team Emergency Assessment Measure; T-NOTECHS = Trauma Non-Technical Skills; ETC = European Trauma Course; ROSC = Return of Spontaneous Circulation; HRV = Heart Rate Variability; ICC = Intraclass Correlation Coefficient; ATLS = Advanced Trauma Life Support; VPS = Virtual Patient Simulation; IPS = In-Person Simulation; PI = Performance Improvement; ED = Emergency Department; RT = Respiratory Therapist; OSCE = Objective Structured Clinical Examination; MHPTS = Modified Hanlon Performance Rating Scale

Ref	Author, Year	Study Design	Sample	NTS Domains Assessed	Key Findings
[25]	Cassidy et al. (2022)	Qualitative (debriefings)	72 participants	Team dynamics, leadership, communication	Identified 6 themes: pre-trauma impact, role identity, resource allocation, leader traits, and interprofessional performance.
[26]	Horne et al. (2024)	Prospective cohort	10 simulations / 120 participants	Pediatric trauma NTS	Showed a 25% overall improvement in performance ($p < 0.01$); initial passes improved significantly across simulations.
[27]	Simmerman-Mabe et al. (2025)	Mixed-methods	62 participants	Cooperation, communication, SA, leadership	Observed better cooperation in blunt vs. penetrating trauma ($p = 0.0069$); role perception improved with color-coding.
[28]	Sfakianos et al. (2026)	Retrospective observational	230 videos / 1,369 scorecards	T-NOTECHS	High inter-rater reliability; higher scores were associated with transferred and non-intubated patients.
[29]	Schreiber et al. (2026)	Cross-sectional survey	124 participants	ATLS, simulation training	ATLS participation was associated with higher perceived safety (3.67 vs. 2.91, $p = 0.0024$).
[19]	Neutel et al. (2023)	Cross-sectional	295 ETC participants	All NTS domains (ETC)	94% changed their clinical

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		survey			approach and 71.4% reported sustained behavioral change following training.
[20]	Botelho et al. (2024)	RCT	45 medical students	All NTS domains (NOTSS)	NTS-focused debriefing significantly improved NOTSS scores (2.13 to 2.75, $p < 0.01$) and ATLS adherence.
[21]	Botelho et al. (2022)	Nominal group technique	7 experts	Debriefing methodology	Developed and validated PEARLS-based debriefing strategies specifically for non-technical skills.
[30]	Hammer et al. (2026)	Retrospective analysis	238 participants	CRM, team communication, decision-making	Identified a three-factor model; healthcare providers demonstrated greater gains in operational competence ($p < 0.01$).
[31]	Ylönen et al. (2025)	Cross-sectional	1,557 trainees	All NTS domains	Trainee experience and age significantly moderated self-assessed non-technical skill improvement.
[32]	Ylönen et al. (2026)	Prospective observational	337 simulations / 1,822 participants	T-NOTECHS	Clinical experience and team size were linked to NTS performance; less experienced staff

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					consistently scored lower.
[33]	Nazir et al. (2025)	Secondary analysis (video review)	30 trauma activations	Communication, leadership, CRM, SA, decision-making	Higher T-NOTECHS scores strongly correlated with fewer adverse events (IRR = 0.89, $p < 0.001$); communication scored lowest.
[34]	Repo et al. (2019)	Validation study	61 simulations / 193 participants	T-NOTECHS validation	Successfully translated T-NOTECHS into Finnish, demonstrating moderate reliability (ICC = 0.54; Cronbach's $\alpha = 0.70$).
[35]	Nazari et al. (2024)	Quasi-experimental	60 nursing students	Clinical skills (9 domains)	Significant improvements were observed across all 9 clinical and skill domains post-training ($p < 0.001$).
[36]	Lamamri et al. (2026)	Cross-sectional	89 participants	Emotional/organizational responses	Emergency professionals reported significantly higher anxiety during major disaster simulations (median 3 vs. 1.5, $p = 0.01$).
[37]	Fernandez et al. (2020)	RCT	79 residents	Leadership	Simulation-based leadership training

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					successfully transferred complex skills into real clinical resuscitation environments.
[38]	**Naus et al. (2024)**	**Pilot study (2-day simulation course)**	**21 surgeons**	**Leadership, communication, clinical reasoning, teamwork**	**Global TRIK course significantly improved knowledge (68% to 76%, $p < 0.001$), self-confidence, and clinical reasoning.**
[39]	**Steinemann et al. (2011)**	**Pre-post**	**137 trauma team members**	**Teamwork, leadership, NOTECHS**	**A 4-hour leadership curriculum improved observed leadership behaviors in real-world trauma resuscitation cases.**
[40]	**Steinemann et al. (2012)**	**Validation study**	**137 team members**	**T-NOTECHS validation**	**Modified the standard NOTECHS framework to create and validate the Trauma NOTECHS (T-NOTECHS) scale.**
[41]	**Miller et al. (2012)**	**Pre-post**	**39 trauma cases**	**Teamwork, communication**	**In situ simulations yielded statistically significant improvements in both teamwork and communication scores.**
[42]	**Roberts et al. (2014)**	**RCT**	**57 medical hospital staff**	**Communication, leadership, teamwork**	**Brief structured training significantly**

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					enhanced overall ad hoc team performance in trauma environments.
[43]	**Long et al. (2019)**	**Pre-post**	**73 trauma patients**	**Team efficiency, simulation**	**Multidisciplinary in situ simulation training measurably improved overall trauma team efficiency.**
[44]	**Capella et al. (2010)**	**Pre-post**	**114 participants**	**Teamwork, simulation, communication**	**Resulted in improved team performance scores and measurable improvements in real clinical patient parameters.**
[45]	**Murphy et al. (2018)**	**Retrospective cohort**	**2,389 trauma patients**	**Non-technical skills, simulation, outcomes**	**Simulation-based team training was directly associated with a reduced time to critical surgical operations.**
[46]	**Anton et al. (2023)**	**Prospective observational (HRV)**	**41 residents**	**Leadership, communication, decision-making, SA, cooperation**	**Higher physiological stress correlated with poorer NTS performance, particularly leadership, communication, and decision-making.**
[47]	**O'Reilly et al. (2011)**	**Mixed-methods evaluation**	**26 participants (9 sites)**	**Team-based trauma reception & resuscitation**	**Significant improvements were shown in resuscitation knowledge and skills across diverse international health systems.**

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[48]	**McLaughlin et al. (2011)**	**Survey-based validation study**	**127 participants**	**Teamwork, communication, leadership, SA**	**84% reported higher confidence in teamwork skills; simulation labs were rated higher than clinical shadowing for readiness.**
[49]	**Westli et al. (2010)**	**Independent group design**	**27 trauma teams / 139 clinicians**	**Coordination, information exchange, authority, SA, supporting behavior**	**Higher-performing teams exhibited better information exchange; shared mental models predicted outcomes better than raw skill scores.**
[50]	**Dumas et al. (2020)**	**Retrospective video review**	**61 resuscitations**	**Assessment & decision-making, leadership, communication**	**Teams scoring highest in assessment and decision-making were 5 times more likely to achieve return of spontaneous circulation (ROSC).**
[51]	**Maiga et al. (2024)**	**Retrospective analysis (TVR)**	**441 hypotensive trauma patients**	**Leadership, communication, decision-making, SA**	**Better NTS performance led to faster transitions; each 1-point worsening in T-NOTECHS added 1.6 minutes to trauma bay time.**
[52]	**Anton et al. (2024)**	**Mixed methods (eye tracking)**	**9 trauma teams**	**Communication, leadership, SA, decision-making**	**Eye-tracking metrics correlated with NTS ratings; longer time-to-first-fixation on equipment negatively impacted performance ratings.**

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[53]	Burke et al. (2017)	Qualitative (focus groups)	55 clinicians	Leadership, communication, confidence, SA	Clinicians strongly valued in situ simulations and highlighted leadership, clear roles, and communication as key elements for trust.
[54]	Cooper et al. (2016)	Quasi-experimental observational	106 resuscitations / 40 nurse raters	TEAM (leadership, teamwork, task management)	Validated the TEAM tool ($\alpha = 0.94$); overall teamwork was strong, but leadership consistently received the lowest scores.
[55]	Cooper et al. (2010)	Tool development	56 videos / 15 live simulations	Leadership, teamwork, task management	Developed and established the construct validity and inter-rater reliability of the Team Emergency Assessment Measure (TEAM).
[56]	Cooper et al. (2013)	Quasi-experimental	44 registered nurses	Leadership, teamwork, task management, SA	Mean overall TEAM score was 57%; participants showed statistically significant improvements in resuscitation knowledge ($p < 0.001$).
[57]	Lapierre et al. (2023)	Pilot RCT	24 trauma professionals	Teamwork, communication, leadership, situational monitoring	Simulation environment (in situ vs. lab) had no significant differential effect on teamwork or cognitive load;

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					validated French TEAM tool.
[58]	Murphy et al. (2019)	Descriptive survey	86 clinicians	Communication, leadership, decision-making, teamwork, organizational factors	Identified 15 key facilitators (e.g., role clarity) and 12 major barriers (e.g., reluctance to question authority) to NTS translation.
[59]	Huffman et al. (2021)	Simulation study	25 first-year residents	Leadership, communication, teamwork, SA	CRM-focused simulation significantly enhanced NTS; scenario repetition and debriefing were more effective than didactic lectures ($p < 0.001$).
[60]	Low et al. (2024)	RCT	40 junior ED doctors	teamwork, communication, decision-making	No significant difference in learning outcomes between virtual and in-person simulations, though satisfaction was higher with in-person methods.
[61]	Beaugé et al. (2026)	Cluster-randomized pre-post	29 teams / 186 participants	Shared mental models (task responsibility, communication)	Both checklist- and algorithm-based in situ trainings improved shared mental models, with no significant difference between formats.
[62]	Anton et al. (2021)	Pilot simulation study	25 residents	Leadership, communication, cooperation, SA	High perceived stress and workload predicted poorer NTS performance, severely

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					impairing decision-making and situational awareness.
[63]	**Maqbool (2025)**	**Prospective mixed-methods**	**53 residents**	**Leadership, communication, SA, decision-making**	**A dedicated simulation workshop significantly boosted leadership confidence and readiness across all NTS domains ($p < 0.001$).**
[64]	**Sochan et al. (2024)**	**Survey-based**	**23 participants**	**Team dynamics, communication, confidence, SA**	**Integrating pediatric in situ simulations into performance improvement processes significantly enhanced provider confidence ($p = 0.023$).**
[65]	**Rosenman et al. (2021)**	**Analysis of RCT data**	**60 residents**	**Leadership, teamwork, patient care**	**revealed no significant gender-based differences in team leadership efficacy or clinical patient care execution.**

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3.2. Leadership Development

Several included studies isolated leadership as the primary training target. In a randomized controlled trial of 79 residents, Fernandez et al. [37] showed that simulation-based leadership training transferred measurably into actual trauma resuscitations, not merely into subsequent simulated encounters one of the few studies in this corpus to demonstrate transfer using real clinical observation rather than simulator data alone. Consistent with this, a four-hour leadership-focused curriculum evaluated by Steinemann et al. [39] in 137 multidisciplinary team members was likewise associated with improved observed leadership behavior during real trauma care. More recently, a prospective mixed-methods study of a dedicated Trauma Team Leader simulation workshop (53 residents) reported significant, sustained gains in leadership confidence [42].

Additionally, less experienced clinicians consistently report lower confidence in leadership roles and slower behavioral adaptation compared to their senior counterparts [16]. This finding indicates that standardized simulation designs may not optimally serve all levels of clinical experience. Junior clinicians may require additional scaffolding, repeated exposure, and graduated complexity before leadership behaviors become sufficiently automated to survive the stress of real clinical encounters.

Notably, one video-based analysis of leadership performance found no significant gender-based differences in either team leadership behavior or downstream patient care, using Bayesian methods that explicitly tested for and did not confirm a leadership advantage associated with either gender [44]. This finding is a useful corrective against assuming that demographic leadership disparities observed in some healthcare settings necessarily translate into measurable performance differences during trauma resuscitation.

3.3. Communication and Teamwork

Communication and teamwork remain the most frequently targeted and evaluated NTS domains in this corpus. Early pre-post studies (Miller et al., 39 cases [41]; Capella et al., 114 participants [44]) and a subsequent randomized trial (Roberts et al., 57 staff members [42]) each reported significant improvements in teamwork and communication scores following brief, structured training. A large multicenter trauma video review (441 patients) further linked better team performance to measurably faster transitions between phases of resuscitation care [51].

Two findings complicate a straightforwardly positive reading of this domain, however. First, in a video-review study explicitly linking non-technical performance to adverse events, communication was the lowest-scoring NTS domain among trauma teams, even as overall T-NOTECHS scores were strongly associated with fewer adverse events (each one-point increase in team score corresponded to an 11% reduction in adverse-event rate) [33]. Second, in a large validity study of the TEAM instrument [54], it was leadership not communication that scored lowest, and larger team size was independently associated with poorer teamwork scores. These two studies, using different tools in different populations, do not agree on which NTS domain is weakest, which itself suggests that "communication" and "teamwork" are not being measured identically across the field. Consistent with this concern, a Norwegian study of shared mental models found that the degree to which team members held a common understanding of the clinical situation predicted patient management outcomes more strongly than teamwork behavior scores per se implying that behavioral checklists alone may be measuring a downstream proxy rather than the cognitive process that actually drives outcomes.

3.4. Situation Awareness and Decision-Making

The clearest outcome-linked evidence in this review comes from this domain. In a retrospective review of 61 trauma resuscitations, teams that scored highest specifically on the "assessment and decision-making" T-NOTECHS subdomain were five times more likely to achieve return of spontaneous circulation [50] notably, the overall T-NOTECHS score was not independently associated with this outcome, suggesting that decision-making performance, specifically, may carry more prognostic weight than aggregate NTS competence. This is reinforced by the multicenter video-review study noted above, in which stronger situational awareness was independently linked to faster completion of transfusion protocols [50].

Two smaller studies used physiological and behavioral markers to probe the mechanisms underlying this domain. An eye-tracking study of nine trauma teams found that time-to-first-fixation on diagnostic equipment

correlated negatively with NTS ratings teams that visually oriented to key equipment more quickly scored better [51]. Separately, two related studies using heart-rate variability as an objective stress marker found that higher physiological stress was associated with poorer NTS performance overall, with the sharpest degradation concentrated in decision-making and situation awareness specifically, rather than spread evenly across all domains [41, 46].

3.5. Psychometric Limitations of NTS Assessment Tools

The two dominant instruments in this corpus T-NOTECHS and TEAM illustrate the field's persistent measurement problems. T-NOTECHS was originally developed by Steinemann et al. [40] as a trauma-adapted modification of NOTECHS, and has since been formally translated and validated in Finnish [13], where it showed only fair inter-rater reliability (single-measure ICC = 0.54; Cronbach's alpha = 0.70). This contrasts with a considerably larger, more recent video-review study (230 videos, 1,369 scorecards) reporting high inter-rater reliability for the same instrument [28] a discrepancy that may reflect differences in rater training, video quality, or scoring protocol rather than a genuine improvement in the tool itself, and which underscores that T-NOTECHS reliability is not a fixed property of the instrument but appears highly dependent on implementation context.

The TEAM instrument shows a more consistent psychometric profile: its original development study established good preliminary validity [55], a subsequent large-scale validity study (106 resuscitation events, 40 nurse raters) reported strong internal consistency (Cronbach's alpha = 0.94) [54], and a follow-up study applying TEAM in a nursing OSCE context reported a total mean score of only 57%, alongside significant knowledge gains post-training [56].

3.6. Curricular Implementation: The European Trauma Course

Data from national implementations of the European Trauma Course (ETC) illustrate the translational gap between educational intervention and clinical practice. As previously noted, while 94% of participants reported a conceptual shift in their approach to trauma care, only 71.4% indicated durable behavioral change following the course [19]. This 22.6 percentage-point discrepancy between attitude change and behavior change is consistent with broader implementation science literature, which demonstrates that knowledge acquisition alone is insufficient to drive sustained practice modification.

The factors influencing this translation are not distributed randomly. Active ETC instructors report higher rates of behavioral integration, likely due to continuous engagement with the curriculum and repeated exposure to its principles through teaching. Conversely, junior clinicians and those lacking prior exposure to advanced trauma courses frequently cite low clinical self-efficacy as a primary barrier to implementing learned behaviors. Systemic factors appear to exert the most significant influence; clinicians consistently identify returning to a clinical department lacking similarly trained peers as the primary obstacle to implementing acquired skills.

This finding has profound implications for institutional training strategy. It indicates that while a robust curriculum is necessary, organizational readiness and a critical mass of trained personnel are essential prerequisites for behavioral transfer. Training isolated individuals, regardless of the quality of the educational experience, is unlikely to produce sustained institutional change if the broader departmental culture does not support the behaviors being taught.

3.7. The Differential Value of Explicit NTS Debriefing

A randomized controlled trial by Botelho et al. [20], involving 45 medical students, provides the clearest experimental evidence in this corpus on debriefing design. NTS-focused debriefing was associated with a statistically significant improvement in NOTSS scores, from a pre-intervention mean of 2.13 to a post-intervention mean of 2.75 ($p < 0.01$), alongside improved adherence to ATLS protocol, relative to standard technical debriefing. The pedagogical structure underlying this intervention was itself developed and validated in a companion nominal-group-technique study by the same group [21], which produced a set of PEARLS-based debriefing strategies specifically targeting non-technical content.

Taken together, these two studies provide reasonably strong evidence that how a scenario is debriefed materially affects whether NTS gains are realized, at least in this trainee population but they do not, on their own, establish that omitting NTS-focused debriefing causes existing skills to decline below baseline. That stronger claim, present in earlier drafts of this manuscript, outpaced what these two sources actually support and should not be carried forward without a source that reports a genuine within-subject decline. Figure 2 presents a conceptual illustration derived from Botelho et al. [20, 21].

4. DISCUSSION

4.1. Reconciling Immediate Educational Gains with Clinical Attrition

The synthesis of the 44 included studies reveals a consistent and troubling pattern in contemporary trauma education. Simulation-based training reliably generates short-term educational gains, demonstrated by moderate-to-large post-training effect sizes across core NTS domains such as leadership and teamwork [12, 18, 44]. However, this laboratory proficiency attenuates significantly upon transition to real-world clinical environments. Evidence of skill retention beyond six months is scarce, and quantifiable correlations between simulation training and patient-centered outcomes remain largely unproven [16, 17, 50].

These findings challenge the prevailing educational assumption that simulation proficiency translates directly into clinical competence. In high-acuity trauma centers, the execution of rehearsed behavioral heuristics is mediated by operational friction (competing clinical demands, fatigue, staffing shortages), cognitive load (the simultaneous processing of multiple deteriorating patients), and systemic barriers (hierarchical cultures that discourage open communication) that conventional instructional designs frequently fail to address. Given the substantial resource allocation required for regular multidisciplinary trauma simulation, understanding the mechanisms underlying this translational failure is essential for optimizing organizational efficiency and ensuring patient safety.

4.2. Demographic Modifiers of Skill Acquisition

Current evidence indicates that NTS acquisition trajectories are significantly moderated by trainee demographic profiles. Cross-sectional data from large trainee cohorts demonstrate that clinical experience and age influence the integration of NTS [5]. Less experienced clinicians generally exhibit lower rates of improvement in teamwork, situation awareness, and decision-making compared to their senior colleagues [3, 5]. This finding is consistent across multiple studies: Hammer et al. [30] reported that providers demonstrated significantly greater gains in operational competence compared to leaders ($p < 0.01$), while Nazari et al. [35] found that all nine clinical

competency domains improved significantly post-training ($p < 0.001$), with the magnitude of improvement varying by baseline experience level.

This demographic variation has direct implications for curriculum design. Lower post-simulation self-assessment scores among younger practitioners may not represent educational failure, but rather a protective self-awareness highlighting the need for continued deliberate practice. A junior resident who recognizes the limits of their leadership capacity after a challenging simulation scenario is arguably demonstrating appropriate metacognition. Conversely, experienced professionals may integrate new behavioural markers more readily through established clinical heuristics, connecting simulation-taught principles to a rich library of prior clinical encounters [42].

Furthermore, individual clinical self-efficacy influences the transition from conceptual understanding to operational execution. Neutel et al. [19] identified that instructor status and self-efficacy were key moderators of the translational gap in the ETC implementation study. A clinician who intellectually endorses the importance of closed-loop communication may still fail to implement it during a real resuscitation if they lack confidence in their authority to direct team members [41]. These observations suggest that standardized trauma curricula may provide insufficient support for junior clinicians while simultaneously under-challenging senior practitioners. Adaptive, tiered simulation designs that adjust complexity and leadership expectations to the developmental stage of the learner may produce more durable behavioural outcomes.

4.3. Structural Impediments and Cultural Inertia

The successful acquisition of NTS in simulation does not guarantee their deployment during actual trauma resuscitation, as execution is constrained by systemic and cultural factors. National implementation data regarding the ETC illustrate this barrier: conceptual endorsement of the curriculum (94%) substantially exceeds the proportion of participants reporting objective behavioural change (71.4%) [4].

The primary systemic impediment is the absence of an institutional critical mass of trained personnel. When a clinician returns to a department where colleagues have not received standardized behavioural training, explicit communication techniques (e.g., closed-loop call-outs or cross-hierarchy assertions) may be socially discouraged or simply met with confusion. Real-world shock rooms are characterized by entrenched hierarchies and professional status differentials that create cultural inertia. Behaviours that are rewarded in a psychologically safe simulation environment, such as a junior nurse questioning a senior physician's diagnostic assumption, may be suppressed under operational pressure if the institutional culture does not actively support these interactions. This finding is reinforced by Cooper et al. [54], who reported that larger team size was independently associated with poorer teamwork scores, suggesting that structural complexity itself may impede effective NTS execution.

Therefore, behavioural transfer must be approached as an implementation science challenge requiring organizational readiness and leadership alignment, rather than a deficiency addressable solely through additional educational sessions. Institutions must consider training as a system-level intervention, not an individual-level one. This requires commitment from departmental leadership, alignment of institutional policies with trained behaviours, and the creation of feedback mechanisms that reinforce NTS in daily clinical practice.

4.4. The Pedagogical Role of Debriefing

The identification of differential responses to debriefing type represents an important finding for educational design. Data from Botelho et al. [20] demonstrate that, in a cohort of 45 medical students, NTS-focused debriefing was associated with statistically significant improvements in NOTSS scores (mean improvement from 2.13 to 2.75, $p < 0.01$) compared to technical-only debriefing [20]. Notably, baseline performance appeared to modify this response: participants with NOTSS baseline scores below 2.29 demonstrated greater absolute improvement gains following NTS-focused debriefing. This observation suggests that not all learners benefit equally from identical pedagogical interventions a hypothesis requiring replication in larger, independent samples [21]. The implications for course design are substantive: debriefing should be structured with intentionality equivalent to the scenario itself. Facilitators require training in behavioral debriefing techniques (PEARLS framework [21], advocacy-inquiry methods [13]) and protected time for interpersonal analysis. This is consistent with Sawyer et al. [66], who demonstrated that debriefing quality ranks among the most critical determinants of simulation learning effectiveness. However, the generalizability of Botelho et al.'s findings to diverse clinical contexts and larger cohorts remains to be established.

4.5. Situating the Review within the Existing Literature

These findings build upon recent comprehensive reviews in the field. Hauta et al. [49] concluded that while diverse training modalities improve acute team performance, robust evidence linking these improvements to patient outcomes remains deficient. Gjeraa et al. [2] similarly identified the paucity of high-quality evidence demonstrating sustained NTS improvement following simulation. Previous reviews, however, have largely stopped short of delineating the specific mechanisms driving this translational gap.

This review addresses that deficiency by identifying organizational readiness, demographic moderators, and debriefing quality as the primary mechanisms determining whether training translates into safer trauma care. This perspective reframes translation failure as a predictable systemic phenomenon rather than an unavoidable limitation of educational methodology. Building upon this synthesis, Section 5 introduces the Simulation-to-Performance Transfer Framework (SPTF), a theoretically grounded model designed to bridge simulation proficiency and clinical trauma excellence.

5. THE SIMULATION-TO-PERFORMANCE TRANSFER FRAMEWORK (SPTF)

5.1. Limitations of Linear Conceptual Models

Contemporary trauma education research frequently relies on a linear conceptual model:

"Simulation → Learning → Performance." This implies that exposing a multidisciplinary team to a high-fidelity scenario automatically results in skill acquisition that seamlessly transfers to clinical practice. The attrition and translational failures identified in this review demonstrate that this linear conceptualization is inadequate. It fails to account for implementation factors (the requirement for longitudinal reinforcement), organizational context (institutional hierarchy and workload surges), demographic influences (the moderating effects of age and experience on learning curves), and non-linear variables (the potential for skill degradation based on debriefing focus).

Existing theoretical models in medical education, while valuable, do not fully address this complexity. The Kirkpatrick model [53] provides a useful taxonomy for evaluating training outcomes across four levels (reaction, learning, behaviour, results), but it is descriptive rather than explanatory; it categorizes outcomes without explaining why transfer fails at specific levels. Competency-Based Medical Education (CBME) [56] emphasizes individual milestone achievement but does not account for the team-level and organizational variables that determine whether individual competencies translate into collective performance. The SEIPS 2.0 model [54] and the Consolidated Framework for Implementation Research (CFIR) [55] analyse organizational architecture but treat clinicians largely as static components within a system, rather than as dynamic agents whose learning trajectories are moderated by individual characteristics.

5.2. Framework Architecture

The SPTF should be interpreted as a hypothesis-generating conceptual framework derived from the thematic synthesis of the available literature rather than as a validated predictive model. Its purpose is to organize current evidence, stimulate future empirical research, and provide a theoretical basis for curriculum development. The SPTF reframes the linear model as an adaptive, multi-level systems approach, mapping the variables necessary to bridge laboratory proficiency and real-world clinical performance. The framework is structured across three interacting domains (see Fig. 3).

The first domain, the Trainee Layer, addresses individual moderators of skill transfer. The experience-cognitive load relationship posits that novice clinicians possess less developed clinical heuristics; consequently, the technical demands of trauma resuscitation consume a larger proportion of their working memory, leaving fewer cognitive resources available for NTS execution.

This is empirically supported by multiple studies in our corpus. Ylönen et al. [16] demonstrated that work experience and age significantly moderate self-assessed NTS improvement, with less experienced clinicians showing lower rates of improvement in teamwork, situation awareness, and decision-making. Hammer et al. [30] reported that providers demonstrated significantly greater gains in operational competence compared to leaders ($p < 0.01$), suggesting that professional role moderates learning outcomes. Similarly, Nazari et al. [35] found significant improvements across all nine clinical competency domains post-training ($p < 0.001$), with the magnitude of improvement varying by baseline experience level. Maqbool [42] reported sustained improvements in leadership confidence at one-year follow-up, with no measurable difference across specialties, suggesting that while leadership can be trained, the baseline experience of trainees influences the trajectory of improvement. The SPTF proposes that simulation designs for junior trainees should utilize low-to-moderate clinical complexity to preserve cognitive capacity for NTS practice. Additionally, the age-self-efficacy relationship indicates that senior professionals tend to integrate behavioural frameworks through established mental models, whereas younger professionals frequently report lower post-training self-efficacy. The framework requires that readiness and psychological safety be assessed prior to training to tailor instructional scaffolding to the specific trainee cohort.

The second domain, the Pedagogical Catalyst, addresses the simulation-debriefing nexus as the operational core of the framework, mapping the educational mechanics required to trigger durable behavioural change. The SPTF establishes that non-technical skills must be allocated dedicated analytical space during guided reflection. Evidence from Botelho et al. [20] demonstrates that NTS-focused debriefing is associated with significantly greater improvements in NOTSS scores ($2.13 \rightarrow 2.75$, $p < 0.01$) compared to technical-only debriefing. Informed

by the data reported by Botelho et al. [20, 21], the framework incorporates a baseline performance observation: participants with higher baseline scores (> 2.29 on NOTSS scales) showed less improvement when debriefing focused exclusively on technical content. This suggests that the effectiveness of debriefing may depend on the learner's baseline competency level.

The third domain, the Systemic Infrastructure, addresses organizational readiness as the primary determinant of sustained behavioural transfer. The SPTF identifies critical mass as the essential systemic modifier. Training isolated individuals is insufficient; a threshold proportion of the department's active workforce must complete the same behavioural curriculum for new heuristics to persist in daily practice. Without this critical mass, trainees returning to untrained environments rapidly abandon learned behaviours due to social pressure and lack of reinforcement.

This is empirically supported by Neutel et al. [19], who found that while 94% of ETC participants reported a conceptual shift in their approach to trauma care, only 71.4% reported durable behavioural change in subsequent practice. Instructor status and clinical self-efficacy were identified as key moderators of this translational gap. Maiga et al. [51] demonstrated in a multicentre video review that better team performance was associated with measurably faster transitions between phases of resuscitation care, but that larger teams were associated with slower performance suggesting that team composition and structure are critical determinants of NTS execution. Cooper et al. [55] further reported that larger team size was independently associated with poorer teamwork scores, reinforcing the importance of team structure as a systemic factor. The proposed framework further suggests the necessity of aligning organizational leadership with simulation objectives, outlining a structural pathway for converting institutional leadership from a potential barrier into an infrastructure that actively supports open communication and shared situation awareness under stress.

5.3. Comparison with Existing Frameworks

The SPTF extends existing models used in medical education and implementation science. While the Kirkpatrick model [67] categorizes evaluation levels, and CBME [68] emphasizes individual technical milestones, neither adequately explains why behavioral transfer fails at the team and organizational level. Similarly, while SEIPS 2.0 [69] and CFIR [70] analyze organizational architecture, they were not designed specifically for the acute, time-critical, multidisciplinary environment of trauma resuscitation. The SPTF integrates individual trainee modifiers, specific pedagogical safeguards against training-induced harm, and systemic infrastructure within a single, coherent structure designed specifically for the acute trauma environment. Its primary contribution is the explicit recognition that transfer failure is a predictable, multi-level phenomenon that can be mitigated through targeted intervention at each domain. Table 2 compares the proposed model with four frameworks widely used in medical education, human factors, and implementation science.

Table 2
Comparison of the SPTF with existing conceptual frameworks

Framework	Core focus	Demographic/ learner modifiers	Captures NTS deterioration risk	Tracks structural/ hierarchical barriers	Non-linear feedback loops
Kirkpatrick model	Linear educational evaluation (reaction → results)	No	No	No	No
CBME pathway	Individual milestone and technical competency	No	No	No	No
SEIPS 2.0	Sociotechnical systems engineering in healthcare	No	Partial	Yes	Partial
CFIR	Multi-level determinants of implementation	No	No	Yes	No
SPTF (proposed)	Multi-level, non-linear simulation-to-performance transfer	Yes	Yes	Yes	Yes

6. FUTURE DIRECTIONS

6.1. Shifting from Descriptive to Predictive Psychometrics

Future validation studies must progress beyond internal reliability testing of NTS scales to establish predictive and ecological validity. Large-scale prospective cohort studies are required to determine whether specific scores on tools such as TEAM or T-NOTECHS during simulation correlate with reductions in clinical error, shortened times to definitive hemorrhage control, or improved patient outcomes in real-world settings. To mitigate observer bias and Hawthorne effects, future study designs should incorporate blinded video audits of actual clinical resuscitations compared against baseline simulation scores. Such studies would require multi-institutional collaboration and substantial ethical oversight but would provide the definitive evidence needed to validate or refine current assessment instruments.

6.2. Quantitative Mapping of Skill Decay and Remediation Curves

While this review documents short-term skill attrition and the potential for training-induced NTS deterioration, the precise trajectories of these behavioral curves remain unmapped. Multi-center longitudinal designs tracking teams at standardized intervals (e.g., 1, 3, 6, and 12 months post-training) are necessary to establish domain-specific skill-decay curves. Controlled trials should evaluate the frequency, duration, and optimal design of "booster" simulation sessions required to stabilize performance above safety thresholds. Understanding whether certain NTS domains (e.g., communication) decay faster than others (e.g., leadership) would allow institutions to target their limited simulation resources more efficiently.

6.3. Mixed-Methods Appraisal of Demographic and Cultural Modifiers

Operationalizing the individual and systemic pillars of the SPTF requires research that acknowledges the heterogeneity of trauma teams. Quantitative modeling should examine how factors such as the novice-to-expert ratio within a team, or the age differential between leaders and followers, moderate collective skill integration. Ethnographic and qualitative methods should be employed to investigate socio-structural barriers to transfer, including how institutional safety culture and departmental leadership alignment can be modified to support open, non-hierarchical team coordination. Research conducted across diverse healthcare systems, including low- and middle-income countries where trauma burden is highest, is particularly needed.

6.4. Technology-Enhanced Scalable Simulation

Frequent, high-fidelity, in-situ multidisciplinary simulation imposes substantial financial and logistical demands on healthcare institutions. Future research should evaluate the educational efficacy and translational capacity of alternative modalities. These include web-based platforms and serious games designed to train situational awareness, triage prioritization, and decision-making prior to physical simulation. Hybrid models combining individual digital training with targeted, in-person team simulation should be assessed to determine whether digital scalability can reduce resource burdens while sustaining clinical skill transfer. The rapid development of virtual reality and augmented reality technologies offers additional possibilities for immersive NTS training that may bridge the gap between cost-effective digital delivery and the interpersonal fidelity required for meaningful team-based learning.

7. LIMITATIONS

This integrative review provides a comprehensive synthesis of NTS simulation for trauma teams; however, several limitations must be acknowledged. First, the literature is subject to publication bias, as studies documenting educational failure, absence of behavioral improvement, or implementation collapse are less likely to be published. This may inflate the apparent efficacy of simulation-based interventions. Second, the included studies exhibited substantial methodological heterogeneity in design, sample size, team composition, simulation fidelity, and duration. This heterogeneity, combined with the predominance of uncontrolled pre/post-test designs relative to randomized trials, precluded a formal quantitative meta-analysis.

Third, the search was restricted to peer-reviewed, English-language publications indexed in PubMed, Scopus, and Web of Science. Relevant data published in other languages, or contained in institutional grey literature and unindexed military trauma registries, may have been omitted. Fourth, the evaluation metrics in the majority of included studies are proximal, relying on immediate post-scenario evaluation within the simulation laboratory. Because longitudinal data and blinded observations of real-world resuscitation are scarce, the capacity of this review to map long-term behavioral decay curves or verify direct clinical transfer remains limited.

Finally, the quantitative thresholds informing the pedagogical pillar of the SPTF are derived from a limited number of related studies by a single research group [20, 21]; these require independent replication across diverse institutional settings and trainee populations before being adopted as fixed benchmarks in curriculum design. The SPTF itself is a theoretical construct that requires empirical validation through prospective implementation studies. Moreover, future prospective multicenter studies will be necessary to validate the

proposed relationships, determine the relative contribution of each pillar, and evaluate whether implementation of the SPTF improves clinical transfer and patient outcomes.

8. CONCLUSION

This integrative review synthesizes evidence that challenges the linear assumption that simulation-based education automatically translates into optimized clinical performance in acute trauma resuscitation. Analysis of 44 empirical studies identifies a translational gap: simulation environments consistently produce substantial, immediate post-training gains in leadership, communication, and coordination, but these behavioural competencies exhibit marked attrition when subjected to the operational friction, professional hierarchies, and cognitive workload of real-world resuscitation.

The review highlights two specific vulnerabilities in current trauma education models. First, individual skill integration is significantly moderated by trainee demographics, specifically age and baseline clinical experience, indicating that standardized curricula may require adaptive modifications to serve heterogeneous learner populations effectively. Second, the design of debriefing materially affects whether NTS gains are realized; NTS-focused debriefing is associated with significantly greater improvements compared to technical-only debriefing, suggesting that the structure of post-scenario reflection is a critical determinant of learning outcomes. This finding demands that course directors and simulation educators prioritize explicit behavioural debriefing as a non-negotiable component of trauma team training.

To narrow this simulation-to-performance gap, future trauma education must move beyond descriptive simulation checklists toward closer alignment with implementation science. The Simulation-to-Performance Transfer Framework (SPTF) proposed here provides a multi-level roadmap integrating individual trainee modifiers, explicit pedagogical safeguards, and the institutional critical mass required to sustain behavioural gains. Transforming simulation from an isolated educational event into a continuous, systems-level safety infrastructure is a necessary step to ensure that educational investment translates into resilient team performance and improved patient-centred outcomes during major trauma care.

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Figures

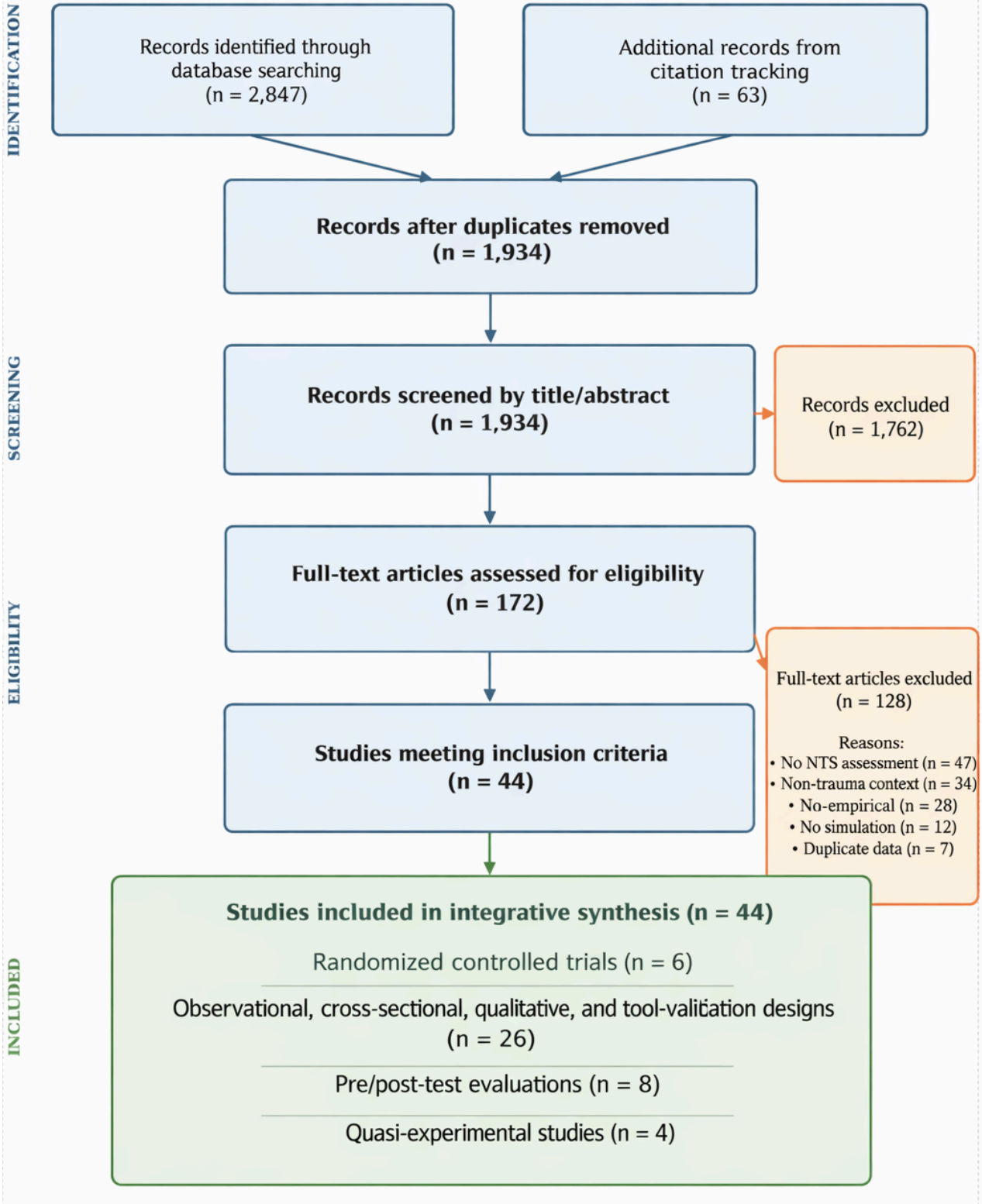


Figure 1

PRISMA 2020 flow diagram documenting the systematic identification, screening, eligibility assessment, and final inclusion of studies for this integrative review

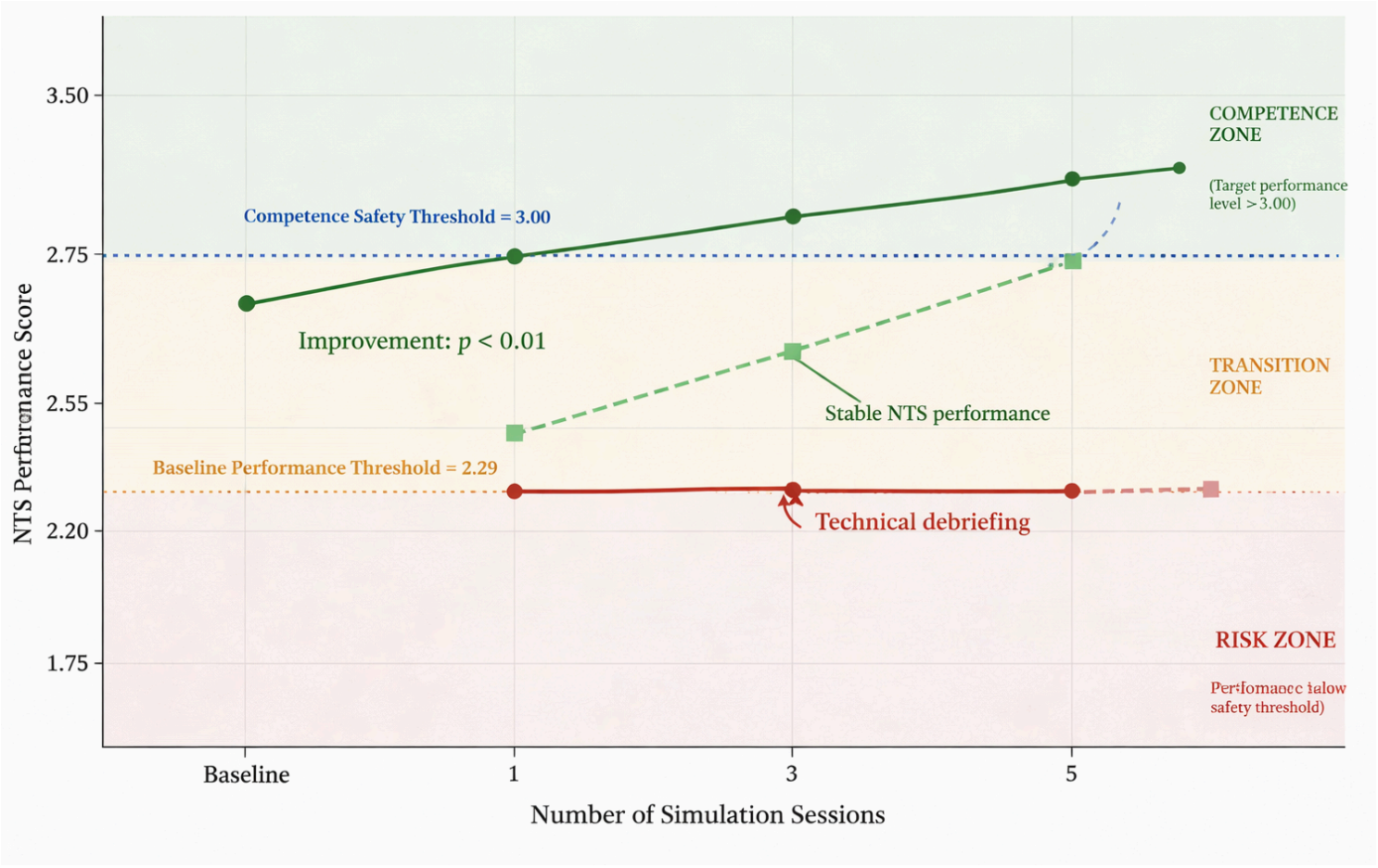


Figure 2

NTS performance trajectories: Effect of debriefing type on skill retention.

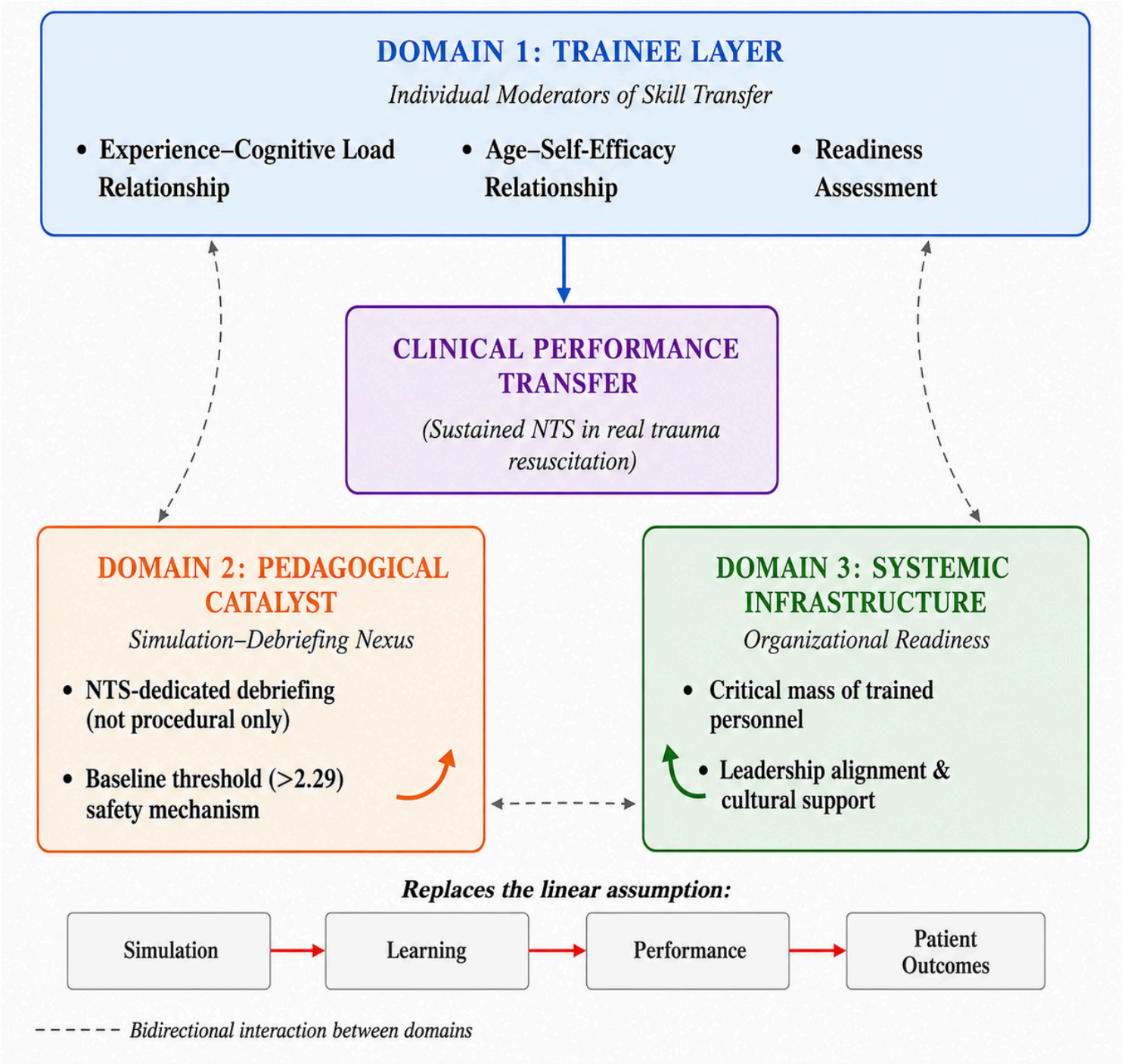


Figure 3

The Simulation to Performance Transfer Framework (SPTF).