

From Simulated Medication Errors to Safer Pharmacy Practice: A Systematic Review of Instructional Design, Assessment Validity, and Evidence of Learning Transfer

Julia Berg^{1*}, Hassan Al-Rashid², Maria Santos³

¹Department of Clinical Pharmacy and Patient Communication, University of Vienna, Vienna, Austria.

²Department of Pharmacy Practice and Patient Counseling, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

³Department of Pharmaceutical Care and Health Behavior, University of São Paulo, São Paulo, Brazil.

*E-mail ✉ julia.berg@univie.ac.at

Abstract

To examine how medication-error simulations in pharmacy education and practice are designed and assessed, the extent to which resulting assessments support valid interpretations of learner performance, and whether improvements demonstrated in simulated settings transfer to clinically relevant behavior or safer pharmacy practice. A systematic review was conducted using PRISMA 2020 reporting principles. Searches captured pharmacy-focused medication-error, medication-safety, error-disclosure, medication-reconciliation, order-verification, root-cause-analysis, dispensing, and related simulation studies. Candidate records were screened against prespecified population, simulation, outcome, and empirical-design criteria. Instructional designs were coded separately from assessment characteristics and from learning-transfer level. Assessment evidence was examined according to construct alignment, scoring processes, reproducibility or assessor agreement, external relationships, and the strength of inference permitted. Transfer was classified from reaction or confidence outcomes through immediate learning, delayed or changed-context performance, workplace behavior, and patient- or safety-level outcomes. Twenty-seven unique candidate records entered the screening process. Seven were excluded during title/abstract or concept screening, leaving 20 for detailed eligibility assessment; three were excluded at that stage, yielding 17 included evidence units. Simulations included root-cause analysis, medication reconciliation, electronic order verification, error disclosure, dispensing and virtual-pharmacy tasks, clinical decision-support scenarios, and error-rich environments. Objective performance measures were present in several studies, but confidence, attitudes, self-assessment, and immediate simulated performance remained common outcomes. Most evidence was confined to proximal educational outcomes or repeated performance in simulated contexts. Direct evidence of workplace transfer was exceptionally limited and vulnerable to attrition and self-report bias. No included evidence established a patient- or medication-safety effect attributable to simulation. Medication-error simulation can support measurable learning and performance within pharmacy education, but the strength of the resulting claims depends on both assessment quality and outcome distance from practice. Current evidence supports educational value more strongly than it supports generalized claims that simulation improves routine-practice medication safety.

Keywords: Pharmacy simulation, Medication errors, Patient safety education, Assessment validity, Learning transfer, Medication safety

Introduction

Medication-error education occupies an unusual position in pharmacy curricula because the target outcome is

ultimately behavioral and safety relevant, while training must occur before learners can independently manage many high-risk situations. A systematic review of entry-to-practice pharmacy patient-safety education found substantial variation in educational approaches, outcome measures, and the depth at which patient-safety competence was assessed [1]. Simulation is attractive within this context because it can expose learners to consequential errors without exposing patients to avoidable harm.

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The interpretive difficulty begins when success inside the simulation is treated as equivalent to success beyond it. Reviews of pharmacy interprofessional simulation and of simulation-based learning transfer in other health professions show that evaluation is concentrated at reaction, attitude, knowledge, and simulated-performance levels, whereas direct observation of transfer into clinical practice is uncommon [2–4]. Even where simulation substitutes for part of conventional clinical experience, heterogeneity in design and outcomes limits claims of equivalence across settings or professions [5].

Assessment quality creates a second problem. Pharmacy education increasingly distinguishes the learning activity from the evidence used to judge learning, emphasizing alignment between the intended competency, the task learners perform, and the inference drawn from the resulting score [6]. High-fidelity or authentic assessment may be valued by learners, but perceived realism and acceptability do not themselves establish that an assessment supports the claimed interpretation [7]. Similarly, confidence and satisfaction can be useful educational outcomes while remaining insufficient substitutes for demonstrated competence [8].

The pharmacy simulation literature is also methodologically diverse. Reviews have documented variation in simulation modality, learner role, authenticity, feedback, facilitation, and outcome selection [9]. Game-based and escape-room approaches further illustrate how engaging instructional formats can generate positive learner responses while leaving downstream behavior largely unmeasured [10]. For medication-error education, this diversity makes a single question such as whether “simulation works” too coarse. This review therefore separates three issues that are often combined: how medication-error simulations are designed; how convincingly their assessments support claims about performance; and how far observed outcomes extend toward real practice. The primary question was: How are medication-error simulations in pharmacy education designed and assessed, how valid are the resulting learning assessments, and what evidence demonstrates transfer from simulation performance to safer pharmacy practice or clinically relevant behavior?

Materials and Methods

Protocol and reporting standard

The review was conducted and reported using PRISMA 2020 principles together with guidance for transparent explanation of systematic-review methods and reproducible search reporting [11–13]. No prospective protocol registration was undertaken, and none is claimed.

The analytical design was specified before synthesis around three separate domains: instructional design, assessment validity, and learning transfer. These domains were kept distinct throughout extraction and interpretation so that, for example, a well-designed simulation could still have weak assessment evidence, and a well-measured improvement in simulation could still lack evidence of practice transfer.

Eligibility criteria

Eligible evidence involved pharmacy students, interns, pharmacists, pharmacy technicians, or mixed health-professions groups in which pharmacy participation and outcomes were sufficiently identifiable. The intervention or exposure had to involve a simulation-based activity materially concerned with medication errors, medication safety, medication reconciliation, dispensing or order-verification errors, error disclosure, root-cause analysis, medication-related problems, or closely related error-prevention tasks.

Eligible empirical designs included controlled and uncontrolled educational interventions, repeated simulation studies, prospective or retrospective assessments, mixed-methods evaluations, and practice-based simulation training. Studies had to report at least one interpretable educational, assessment, performance, behavioral, or transfer outcome.

Records were excluded when pharmacy participants were absent or their findings could not be separated meaningfully; when the simulation was unrelated to medication safety or medication-problem recognition and management; when no empirical assessment outcome was reported; or when the intervention was not educational or training oriented. Journal quartile was not an eligibility criterion.

Information sources and search strategy

Searches were executed on 13 September 2026 using PubMed-indexed scholarly discovery with PubMed, PubMed Central, and publisher records used for bibliographic and content verification. Searches combined pharmacy population terms with simulation and medication-safety concepts.

The core search logic included combinations of: pharmacy, pharmacy student, pharmacist, or pharmacy technician with simulation, simulated patient, virtual simulation, MyDispense, or electronic health record, together with medication error, patient safety, dispensing error, order verification, medication-related problem, error disclosure, root cause analysis, or medication reconciliation. A complementary transfer search combined simulation-based education with learning transfer, clinical practice, assessment, and validity concepts.

Candidate records were canonicalized using DOI, PMID, title, and publisher information during capture. Repeated manifestations of the same report were therefore suppressed before entry into the screening process rather than recorded as a separate duplicate-removal stage.

Study selection

Screening proceeded in two stages. First, titles, abstracts, and available indexing information were assessed for pharmacy relevance, medication-error or medication-safety simulation content, and the presence of an empirical educational or performance outcome. Records passing this stage underwent detailed assessment against the full eligibility criteria.

The screening process was reconciled at each transition. Exclusion categories were mutually interpretable and were assigned according to the principal reason that a record failed eligibility. Review-method, background, assessment, and transfer sources used to define methods or interpret findings were maintained separately from the included empirical evidence units.

Data extraction

Extraction was performed at the evidence-unit level. Fields included study design; country or region; educational or practice setting; participant group; sample size when reported; simulation intervention; comparison condition where applicable; medication-safety task; assessment target; measurement method; follow-up period; principal finding; contradictory or null finding; stated limitation; applicability boundary; and the strongest claim supported by the reported data.

Missing information was retained as unreported rather than inferred. Outcomes were extracted in the form in which authors reported them, without converting qualitative findings, proportions, rubric scores, or noncomparable educational measures into a common effect metric.

Coding of instructional design

Instructional design was coded independently of study outcome. The coding dimensions were simulation modality, medication-safety problem, learner role, fidelity or contextual authenticity, individual versus interprofessional participation, feedback or debriefing, repetition, and the mechanism by which the activity was intended to support learning.

The evidence base included root-cause-analysis simulations directed at medication errors [14], error-disclosure exercises that incorporated learner and faculty assessment [15], electronic health-record order-verification tasks with embedded medication errors [16], and interprofessional medical-error simulations combining structured scenarios with reflection [17]. Medication-reconciliation simulations provided a distinct practice-authentic task centred on obtaining and evaluating medication information [18], while acute-care simulations extended assessment toward integrated clinical reasoning [19]. Community-pharmacy simulation further illustrated how a repeated practice environment could be embedded longitudinally within therapeutics teaching [20].

Design categories were not ranked a priori. A technologically complex or highly authentic simulation was not assumed to be educationally superior unless comparative evidence supported that conclusion.

Assessment-validity framework

Assessment validity was treated as an argument about the interpretation of performance rather than as a property conferred by simulation fidelity alone. Five dimensions were coded: alignment between the assessment task and claimed competency; the objectivity and transparency of scoring; assessor structure and agreement where relevant; evidence of reproducibility; and relationships between assessment performance and other meaningful indicators.

Virtual objective structured clinical examination practice demonstrated how a simulation can produce measurable performance information while still leaving open the question of how well that performance represents clinical practice [21]. Comparisons of virtual and conventional communication assessments similarly support bounded claims about measured communication performance rather than unrestricted claims about practice competence [22]. Difficult-patient simulations showed that improvement in self-rated communication may occur without an independent workplace criterion [23].

Where follow-up existed, its evidentiary meaning depended on what was retested. A one-month knowledge-retention comparison provides stronger temporal evidence than an immediate post-test but remains educational rather than workplace transfer [24]. Inter-rater reliability evidence from telehealth assessment strengthens confidence in scoring consistency without establishing the entire validity argument [25]. Simulated telehealth counseling likewise supports direct assessment of observable performance but not a patient-outcome claim [26]. Comparative virtual-patient studies can test whether one learning format produces different examination performance from another, while the inference remains bounded by the assessment used [27].

Definition and coding of learning transfer

Learning transfer was defined prospectively as the extent to which an outcome moved beyond reaction to the educational activity and beyond performance confined to the original simulated setting. Five outcome tiers were used.

T0 comprised reaction, satisfaction, attitudes, or confidence without demonstrated performance. T1 comprised immediate knowledge, skill, or performance within the trained simulation context. T2 comprised delayed retention or performance in a changed or repeated simulated context. T3 required observed or reported behavior in authentic workplace practice. T4 required a patient, clinical, medication-error, or other safety-relevant outcome occurring in practice.

This hierarchy described evidentiary distance rather than educational worth. A rigorous T1 assessment could be more valid for its intended claim than a weakly measured T3 outcome. National use of virtual dispensing environments illustrates the broad implementation of simulation tools without by itself establishing transfer [28], while introductory virtual-pharmacy exercises show how early training can target knowledge and confidence before practice exposure [29].

Risk-of-bias/quality assessment

Because the evidence set contained heterogeneous educational designs, quality was appraised using claim-specific domains rather than a single pooled score. The domains were comparator and confounding control; completeness of participant data and follow-up; objectivity of outcome measurement; evidence supporting the assessment instrument or rubric; temporal

horizon; whether the assessment context differed meaningfully from the training context; whether behavior was observed in workplace practice; and applicability to the population and setting of interest.

A study could therefore provide relatively strong evidence for a narrow simulated-performance claim while providing little or no evidence about transfer. Attrition, self-report, historical controls, assessor disagreement, small samples, and absence of delayed or workplace outcomes were treated as limitations on the corresponding inference rather than automatic reasons for exclusion.

Synthesis

Clinical and methodological heterogeneity precluded a defensible common effect estimate. The studies differed in educational setting, learner stage, intervention, error type, comparator, assessment instrument, outcome scale, assessor, and temporal horizon. A structured narrative synthesis was therefore performed.

The synthesis crossed three independently coded dimensions: instructional configuration, assessment-inference strength, and T0–T4 transfer level. Contradictory or null findings were retained within these dimensions instead of being collapsed into a global positive-versus-negative judgment. Patterns were interpreted in light of appraisal domains, with particular emphasis on the distinction between simulated performance and evidence of behavior or safety outcomes in practice.

Results and Discussion

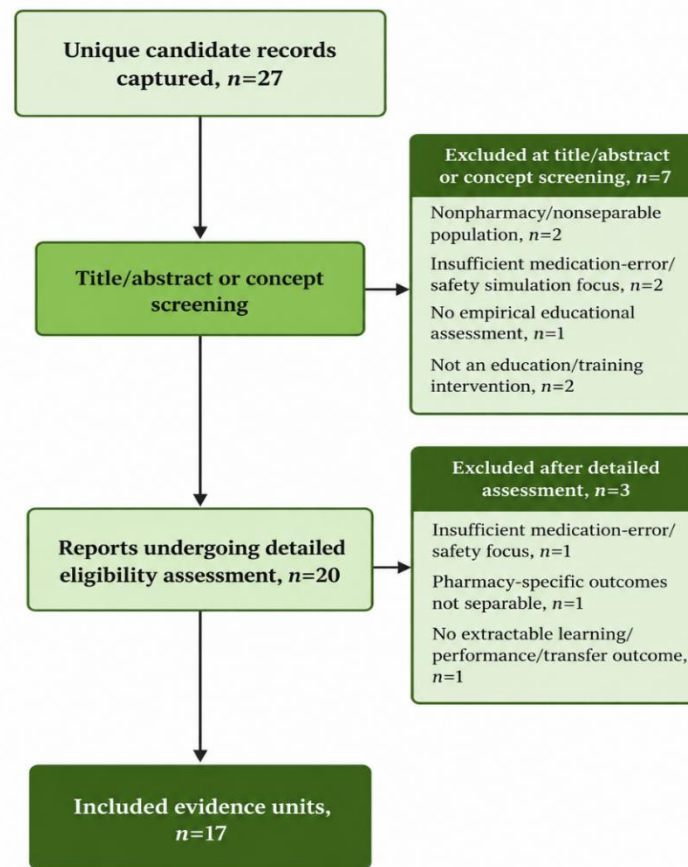
Study selection

Twenty-seven unique primary-study candidate records entered the screening process. Seven were excluded at title/abstract or concept screening: two because the population was nonpharmacy or pharmacy findings could not be separated, two because the intervention was not sufficiently related to medication error or medication safety, one because no empirical educational assessment was reported, and two because the activity was not an education or training intervention.

Twenty records proceeded to detailed eligibility assessment. Three were excluded: one because the intervention was not sufficiently centered on medication-error or medication-safety problem identification or management, one because pharmacy-specific outcomes were not separable, and one because no extractable

learning, performance, or transfer outcome was available. Seventeen evidence units were included in the review.

The resulting arithmetic is shown in **Figure 1**.



Note: Reference allocation $\neq$ included evidence count.

Figure 1. Study selection for the systematic review of medication-error simulation in pharmacy education and practice

Study characteristics

The 17 included evidence units spanned student and practitioner education, with most conducted in university pharmacy programs and a smaller number involving practicing pharmacy personnel. Early studies included root-cause-analysis-based medication-error simulations demonstrating proximal changes in knowledge, skills, and attitudes [14] and interprofessional error-disclosure training in which learner self-assessment could be compared with faculty judgments [15]. Electronic health-record order verification provided a more task-specific approach to identifying medication problems [16], while interprofessional error scenarios broadened

the assessment toward teamwork, communication, and disclosure [17].

Medication reconciliation represented another recurring safety-critical task [18]. Acute-care simulations linked medication-problem identification with broader clinical performance [19], whereas community-pharmacy environments provided repeated exposure to simulated patient care [20]. Subsequent work expanded into virtual OSCE preparation [21], remotely delivered communication assessment [22], difficult-patient encounters [23], delayed knowledge-retention comparisons [24], rubric-based telehealth assessment [25], simulated telehealth counseling [26], virtual-patient pharmacotherapy exercises [27], implementation of

MyDispense across US pharmacy programs [28], and introductory virtual-pharmacy learning for first-year students [29].

The evidence base was consequently broader than medication-error disclosure alone, but highly

heterogeneous in what counted as successful performance. **Table 1** distinguishes the major characteristics of the included evidence units without treating study description as an effectiveness judgment.

Table 1. Included medication-error simulation evidence units and the educational or practice context in which performance was assessed

Study/year	Population and setting	Medication-safety problem	Simulation context	Study design / assessment orientation
Poirier 2017	Pharmacy, nursing, and dental students	Disclosure of an error	Interprofessional disclosure scenario with video review	Prospective multi-assessor evaluation
Frenzel 2018	P3 pharmacy students	Medication errors and contributing systems factors	Three pharmacy scenarios with root-cause analysis	Pre/post educational intervention
Motycka 2018	Mixed health-professions students	Medication-management errors	Interprofessional TeamSTEPPS-linked scenarios	Pre/post attitude evaluation
Cooper 2019	Pharmacy students	Hospital medication errors and omissions	Patient-specific clinical-skills activities	Performance and item-analysis study
Bajis 2019	Pharmacy students	Medication history and reconciliation problems	Role-play with immediate feedback	Simulation/feedback intervention
Komperda 2019	P3 pharmacy students	Medication reconciliation	Standardized-patient encounter	Comparative educational intervention
Marshall 2020	Mixed health-professions students	Medical-error disclosure	Realistic interprofessional simulation	Mixed-methods pre/post evaluation
Ives 2020	P2 pharmacy students	Inpatient order-verification errors	Electronic health record	Historical comparative cohort
Frenzel 2020	Pharmacists and technicians	Medication-error investigation and improvement	Continuing-education RCA simulations	Intervention with delayed follow-up
Chuang 2021	First-year pharmacy students	Dispensing and labeling errors	MyDispense assessment	Retrospective assessment analysis
Cole 2021	Pharmacists and technicians	Medication errors and RCA	Escape-room continuing education	Pilot evaluation
Dupree 2022	P2 pharmacy students	Drug-therapy problems in order verification	Simulated inpatient verification	Multi-year educational evaluation
Baalmann 2023	Medical and pharmacy students	Medication-error disclosure	Telehealth interprofessional encounter	Pre/post plus faculty rubric
Stultz 2023	Pharmacy students	Medication-related problems with CDS alerts	Repeated order-verification simulation	Randomized/repeated simulation
Aljuffali 2023	Senior PharmD students	Detection of embedded medication-safety hazards	Error-rich simulated environment	Mixed quantitative/qualitative evaluation
Hincapie-Castillo 2023	Pharmacy students	Medication error and contributing system factors	Multi-perspective video plus RCA	Pre/post instructional evaluation
Garnier 2023	Hospital oncology pharmacy personnel	Cytotoxic-production errors	Production “room of errors”	Small pre/post simulation study

Simulation designs

The interventions differed not simply in technological fidelity but in the work learners were asked to perform. Some simulations centered on reconstructing how an

error occurred; others required prospective detection, medication reconciliation, clinical verification, disclosure, or coordinated teamwork. Virtual-pharmacy and EHR-based tasks created opportunities for repeated

individual decisions, whereas standardized-patient, telehealth, and interprofessional simulations emphasized communication and role interaction.

This heterogeneity matters because different designs expose different failure modes. A learner may perform well in root-cause analysis yet still miss an active order-verification problem; strong communication during disclosure does not necessarily indicate accurate

detection of the preceding medication error. Likewise, increasing realism does not automatically strengthen learning unless the task, feedback, repetition, and assessment remain aligned.

The design coding used in **Table 2** therefore treats simulation configuration as a set of educational choices rather than as a single fidelity hierarchy.

Table 2. Instructional configurations used to teach recognition, analysis, prevention, or communication of medication errors

Design configuration	Typical learner task	Error representation	Learner role	Feedback/debriefing pattern	Repetition / temporal structure	Educational mechanism most directly engaged
Root-cause-analysis simulation	Identify contributing factors and propose prevention	Completed or reconstructed error event	Investigator / improvement team	Facilitated analysis or post-scenario discussion	Usually discrete scenario set	Systems thinking and causal reconstruction
Electronic order verification	Accept, modify, or reject medication orders	Embedded medication-related problems	Pharmacist verifier	Score review and instructional feedback	Often repeated across cases	Prospective detection and decision discrimination
Medication reconciliation	Obtain, compare, and reconcile medication information	Omissions, discrepancies, incomplete histories	Medication-history/reconciliation pharmacist	Standardized-patient or faculty feedback	One or several encounters	Information integration and discrepancy resolution
Error disclosure	Explain an error and respond to patient/team concerns	Known adverse event or error	Pharmacist / interprofessional team member	Faculty, peer, video, or reflective review	Usually single structured event	Communication, accountability, and disclosure behavior
Virtual dispensing pharmacy	Process prescriptions and identify dispensing problems	Prescription, label, counseling, or supply errors	Community pharmacist	Automated or instructor feedback	Repeated prescriptions/cases	Workflow practice and error recognition
Error-rich environment / room of errors	Search for multiple hazards and prioritize them	Simultaneous visible and procedural errors	Safety observer / team member	Post-activity debrief	One concentrated exercise	Situational awareness and hazard detection
Clinical decision-support simulation	Respond appropriately with or without alerts	Medication problems with variable decision support	Order verifier	Performance feedback across sessions	Repeated exposure	Resistance to automation bias and cue dependence
Telehealth / virtual communication simulation	Counsel, disclose, or manage medication problems remotely	Medication-related communication challenge	Remote pharmacist	Faculty rubric and/or learner reflection	Usually discrete encounter	Observable communication under remote-care constraints

Assessment validity

The reviewed studies differed substantially in what their assessments allowed investigators to claim. Reviews of entrustable professional activities provide a useful workplace-oriented contrast because entrustment concerns performance that can support increasingly independent professional responsibility [30]. Concerns about the quality of EPA assessment likewise emphasize that professional-looking tasks require defensible measurement before they can justify consequential judgments [31].

Within the medication-error simulation evidence, some assessments were dominated by self-report. Others used objective correct/incorrect verification decisions, embedded error counts, structured rubrics, or comparisons across assessors. Telehealth error-disclosure simulation, for example, combined confidence outcomes with a faculty-scored performance rubric [32]. Repeated medication-order verification with

and without clinical decision-support alerts provided objective decision data across successive simulations and showed improvement over repeated exposure [33]. In an error-rich simulated environment, learners identified only a portion of the embedded hazards while also demonstrating observable teamwork behaviors, making the distinction between safety detection and nontechnical performance especially visible [34].

Validity judgments were consequently claim specific. A reliable rubric strengthened the interpretation of rubric-scored performance; it did not establish that the learner would behave identically in an uncontrolled workplace. Objective detection of simulated errors provided stronger evidence than confidence alone for error-recognition competence, but it still remained evidence from a constructed environment. **Table 3** makes these distinctions explicit.

Table 3. Assessment approaches and the strongest inference supported by the available validity evidence

Assessment approach	Assessment target	Typical task or instrument	Scoring / assessor structure	Validity-relevant evidence available	Strongest defensible claim
Confidence or attitude questionnaire	Perceived readiness, confidence, teamwork or safety attitude	Pre/post self-report scale	Learner self-report	Temporal change; sometimes established questionnaire structure	Perceived change in confidence or attitude
Knowledge test	Medication-safety concepts or error-analysis knowledge	MCQ or structured knowledge items	Objective answer key	Score change and, occasionally, delayed retention	Knowledge acquisition or retention
Simulated error-detection count	Recognition of embedded hazards	Identify errors in a room, prescription, order, or workflow	Objective number/type of errors detected	Direct correspondence with predefined embedded errors	Performance in detecting specified simulated hazards
Order-verification decision	Appropriate response to medication-related problems	Accept/reject/modify orders; respond with or without CDS	Objective or rule-based decision score	Repeated measures; problem-specific response patterns	Accuracy of simulated verification decisions
Structured performance rubric	Communication, disclosure, telehealth or integrated performance	Standardized/simulated encounter	Faculty or trained raters	Inter-rater agreement, structured criteria, sometimes predictive relationships	Scored performance on the defined simulated task
Self-versus-assessor comparison	Calibration of learner self-judgment	Learner rating compared with faculty or external rating	Multiple assessor sources	Degree and direction of agreement/disagreement	Accuracy or limitation of self-assessment
Delayed educational reassessment	Persistence or generalization of learning	Repeated knowledge or simulated task after time/context change	Same or modified assessment	Temporal separation from training	Delayed retention or changed-context simulated performance

Workplace follow-up	Behavior after return to practice	Survey or observed professional activity	Self-report or external observer	Context authenticity; vulnerable to follow-up completeness	Practice behavior only to the extent directly measured
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Across these assessment forms, the evidence was strongest when the task, scoring method, and claim were tightly aligned. The central limitation was not absence of positive educational findings, but the much smaller body of evidence capable of supporting inferences beyond the simulated environment.

Evidence of learning transfer

The transfer analysis produced a markedly different picture from the generally favorable immediate educational findings. Most included studies ended at reaction, confidence, knowledge, or performance within the simulated environment. These outcomes were classified as T0 or T1 because the learner remained either within the perceptual domain or within the context in which instruction was delivered.

Several studies moved farther by testing learners after time had elapsed, presenting new cases, or exposing them repeatedly to related medication-safety problems. Delayed knowledge assessment and repeated order-verification tasks therefore met the review definition of T2 when learners had to retain or generalize prior learning across time or altered simulated conditions. Such outcomes provide stronger evidence than an immediate post-test because performance is no longer wholly dependent on the original instructional episode. They nevertheless remain assessments conducted under educationally constructed conditions.

The clearest example was repeated medication-order verification with and without clinical decision-support alerts. Performance improved across successive

simulated encounters, including cases in which alerts were absent [33]. This pattern is consistent with generalization beyond a single exposure, but the outcome remained verification behavior in simulation. It therefore supports T2 transfer rather than an inference that medication-order decisions improved in routine clinical practice.

Direct evidence at T3 was scarce. One continuing-education study followed pharmacists and pharmacy technicians 14 months after medication-error and root-cause-analysis simulation. Among the 15 respondents available at follow-up, two reported implementing a practice change and nine reported reinforcement of existing practice. The long interval and workplace orientation are important strengths for the transfer question, yet interpretation is constrained by the very low follow-up participation relative to the original training cohort. The evidence therefore indicates that workplace transfer can occur but does not provide a stable estimate of its frequency or magnitude.

No included evidence unit demonstrated T4 transfer through a measured reduction in medication errors, preventable harm, clinically consequential prescribing or dispensing errors, or another patient-level safety outcome attributable to simulation. The absence of T4 evidence does not imply that simulation has no safety effect; it identifies the point at which the available empirical chain ends.

Table 4 summarizes the transfer claims that the included evidence can support.

Table 4. Distance between medication-error simulation outcomes and routine-practice safety claims

Transfer level	Outcome represented	Typical evidence observed in the review	Context change from training	Strongest claim permitted	Principal limitation for stronger inference
T0 — Reaction / perception	Satisfaction, confidence, attitudes, perceived readiness	Pre/post questionnaires; reflections; learner perceptions	None required	The simulation changed how participants perceived their knowledge, confidence, role, or preparedness	Self-report provides no direct evidence of competent performance
T1 — Immediate	Knowledge, error detection, rubric score,	Knowledge tests; simulated-patient	Minimal	Participants learned or	Performance remains closely

learning / performance	communication or verification performance immediately after training	scoring; embedded-error counts; immediate order-verification decisions		performed better on the assessed educational task	coupled to the instructional environment
T2 — Delayed or changed-simulation generalization	Retained knowledge or performance across later or modified simulated cases	Delayed testing; repeated order verification; response to cases with changed decision-support conditions	Temporal and/or simulated-context change	Learning persisted or generalized across educationally constructed conditions	Generalization remains inside simulation rather than routine workplace practice
T3 — Workplace behavior	Use of learned practices after return to professional work	Delayed self-reported practice change or reinforcement	Authentic work setting	Some participants reported or demonstrated changed professional behavior	Evidence was exceptionally sparse and vulnerable to attrition and reporting bias
T4 — Patient / medication-safety outcome	Medication-error incidence, preventable harm, clinically consequential safety outcome	No qualifying included evidence established this level	Full practice and patient-outcome context	No review-level effectiveness claim permitted	The causal chain from simulation to patient safety was untested

The distribution across these levels was strongly asymmetric: the evidence base was comparatively substantial at T0–T2, very limited at T3, and absent at

T4. **Figure 2** integrates this pattern with the instructional-design and assessment-validity findings.

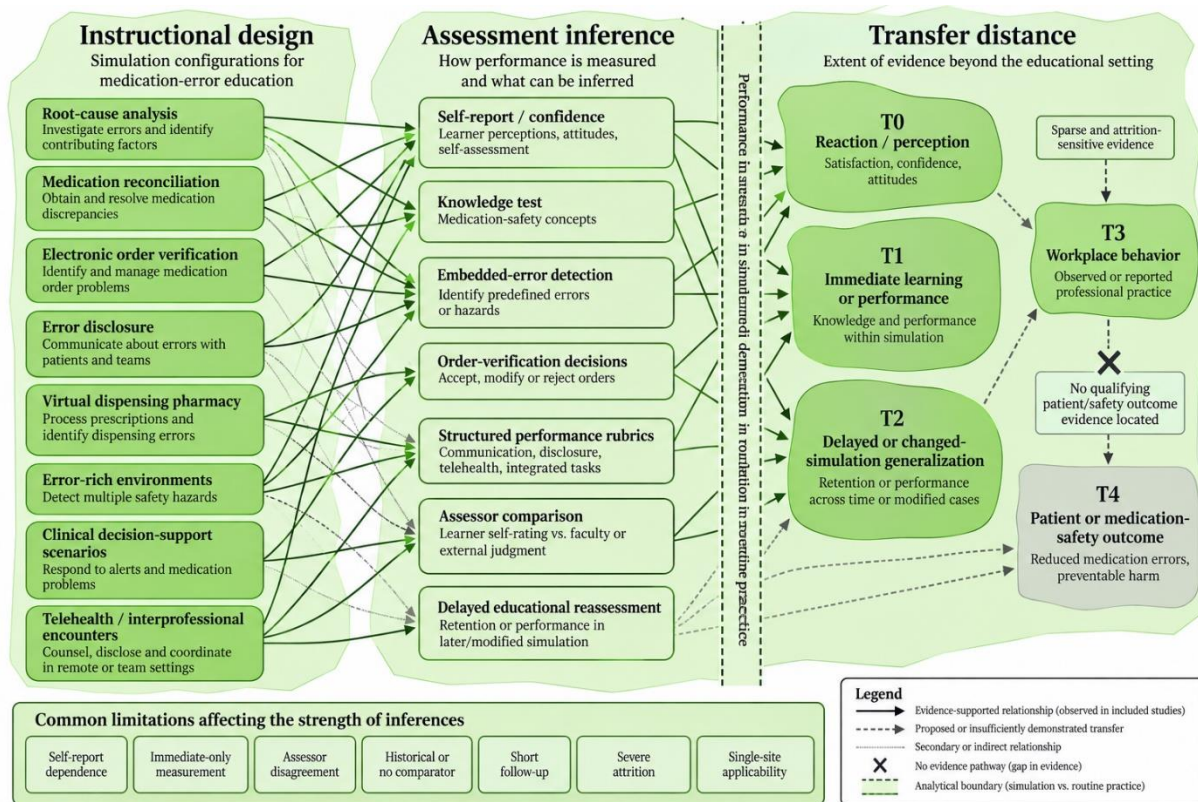


Figure 2. Where medication-error simulation evidence supports learning claims—and where the chain toward safer practice becomes uncertain

Quality of evidence

The overall evidence base supported greater confidence in claims about immediate educational performance than in claims about behavior beyond the simulation. Several studies used objective error counts, order-verification decisions, structured rubrics, or multiple assessors, improving the credibility of narrow performance interpretations. Repeated exposure and delayed testing further strengthened evidence for retention or changed-context performance.

Important limitations were nevertheless recurrent. Many studies used single-group pre/post designs, historical rather than concurrent comparison groups, or outcomes based principally on confidence and attitudes. Sample completeness varied, and delayed follow-up was uncommon. When longer follow-up was attempted, attrition could be substantial. Measures with apparently high authenticity sometimes had limited documented validity evidence, while reliable scoring alone could not establish that performance would generalize to routine practice.

Heterogeneity also prevented a single quality judgment from characterizing all evidence. A study could be methodologically persuasive for one question and weak for another. Objective detection of embedded errors could support a claim about simulated hazard recognition while remaining uninformative about workplace safety outcomes. Conversely, a long-term workplace survey was closer to the transfer construct but could be weakened by self-selection, recall, and incomplete response. Quality was therefore interpreted in relation to the exact claim being made.

This systematic review indicates that medication-error simulation in pharmacy education has a credible educational role, particularly for rehearsing error recognition, investigation, verification, reconciliation, disclosure, and related communication. The strongest evidence concerns what learners can demonstrate during or after designed educational activities. The central uncertainty emerges when those findings are extended to routine-practice medication safety.

Simulation can address complex professional work that is difficult or unsafe to reproduce opportunistically in clinical placements. Other pharmacy simulations have similarly been used to cultivate competencies requiring integrated judgment and communication [35]. Yet realism alone does not determine the meaning of a performance score. The reviewed evidence showed

substantial variation in assessor type, scoring structure, task definition, and outcome selection.

Differences between self-assessment and external judgment reinforce this point. Pharmacy education research has shown that learner self-ratings and externally judged performance may diverge, including when practice-based assessors are involved [36]. Within medication-error simulation, this makes confidence valuable as a learner-centered outcome but unsuitable as a stand-alone indicator that a participant can reliably identify or manage errors.

Temporal persistence also varied according to what was measured. Pharmacy patient-safety education has shown that favorable attitudinal change can attenuate during follow-up [37]. Such patterns make delayed assessment important, but delayed confidence or attitude still differs conceptually from observed professional behavior. The transfer construct must therefore specify both when reassessment occurs and what is reassessed.

The distinction is further illustrated by evidence comparing pharmacy learners with more experienced pharmacy personnel. Simulation studies can reveal differences in the ability of students, pharmacists, and support staff to manage the same clinical problem [38]. This supports the value of simulation as a diagnostic and formative environment because performance deficits can be exposed under controlled conditions. It does not by itself establish the consequences of those deficits—or their correction—for actual patient outcomes.

The broader health-professions literature reaches a similar conclusion: clinical-practice transfer is measured far less frequently than immediate educational outcomes, and the relatively small transfer literature often relies on self-reported or short-horizon measures [2–4]. This convergence strengthens the interpretation that the gap identified here is methodological rather than unique to one set of pharmacy simulations.

Three findings follow. First, medication-error simulation is not one intervention. Root-cause analysis, dispensing, medication reconciliation, order verification, error disclosure, and error-rich environments exercise different cognitive, procedural, and interpersonal functions. Second, assessment validity determines the claim that may legitimately follow from a simulation result. Objective performance evidence can support stronger claims than satisfaction alone, but the claim remains bounded by the task and validation evidence. Third, learning transfer constitutes an independent dimension. Strong T1 performance cannot be relabeled

as T3 simply because the simulation resembles clinical practice.

The evidence therefore supports a conditional interpretation of the article title. Simulated medication errors can contribute to safer-practice preparation by providing structured opportunities to encounter, analyze, and manage medication-safety problems. Current studies do not establish a general causal pathway from participation in simulation to fewer medication errors or improved patient-safety outcomes in routine pharmacy practice.

Implications for pharmacy education

Simulation design should begin with the behavior educators intend learners eventually to perform. When the aim is systems thinking, root-cause analysis may be appropriate; when the aim is prospective error detection, order-verification or dispensing tasks may provide better alignment; when the aim is disclosure or team coordination, standardized-patient or interprofessional designs may be necessary.

Assessment should then be matched to that objective. Confidence and satisfaction can identify learner experience, but they should not substitute for performance when competence is the intended claim. Error counts, decision accuracy, structured rubrics, and trained assessor judgments offer more direct evidence for performance, provided scoring processes are sufficiently transparent and reproducible.

Programs seeking evidence of transfer should deliberately assess beyond the educational encounter. Delayed simulation can test retention and generalization, but claims about practice require workplace-linked outcomes. These could include structured preceptor observations, practice-based medication-safety behaviors, documented verification decisions, error-reporting or reconciliation performance, and carefully governed patient-safety indicators where attribution is scientifically defensible.

Educational programs should also avoid treating a more technologically sophisticated simulation as inherently stronger. The instructional value of a design depends on the medication-safety function being rehearsed, the opportunities for feedback and repetition, the assessment evidence generated, and the level of transfer the curriculum is intended to achieve.

Strengths and limitations

A principal strength of this review is the explicit separation of instructional design, assessment validity, and learning transfer. This prevents positive learner reactions, confidence changes, or immediate simulated performance from being combined into an undifferentiated claim of safety effectiveness. The extraction strategy also retained null findings, assessor disagreement, partial error detection, and limitations affecting the inference permitted from each study.

The heterogeneous evidence base was synthesized without forcing statistically incompatible outcomes into a pooled estimate. Transfer was defined before synthesis, allowing delayed educational outcomes and workplace behavior to remain analytically distinct.

Several limitations constrain interpretation. The executed search relied on tool-accessible PubMed-indexed discovery and verification rather than direct export from multiple subscription databases. The resulting review should therefore be understood as systematic within the executed search environment rather than as proof that every potentially eligible international report was captured. Publication terminology was inconsistent, and medication-safety simulation sometimes overlapped with broader communication, clinical skills, or interprofessional education. The evidence base was also dominated by educational settings, frequently within single institutions, limiting generalizability to practicing pharmacists and diverse health systems.

A further limitation concerns transfer assessment itself. Because few studies measured authentic workplace behavior, the review's strongest conclusion is about the absence of demonstrated transfer evidence rather than absence of transfer as a phenomenon.

Future research

Future studies should connect simulation performance prospectively with outcomes obtained after learners enter authentic practice. Longitudinal designs could test whether performance on medication-order verification, reconciliation, disclosure, or error-detection simulations predicts corresponding behaviors during experiential education or early professional practice.

Assessment development should document the evidence supporting score interpretation rather than reporting only learner satisfaction or internal consistency. Studies using rubrics should evaluate assessor training, agreement, decision thresholds, and relationships with external measures where feasible.

Research should also distinguish retention from transfer. A repeat test weeks later is valuable evidence of learning persistence, while a different task, setting, or workflow provides evidence about generalization. Workplace observation is required for stronger claims about professional behavior. Patient-safety outcomes require additional safeguards against confounding because medication-error rates depend on staffing, technology, workload, reporting culture, organizational systems, and many factors beyond individual simulation training. Comparative studies are also needed to determine which instructional features matter. Fidelity should be decomposed into clinically meaningful components such as decision responsibility, information availability, time pressure, team interaction, feedback, repetition, and error consequence rather than treated as a single high-versus-low property.

Conclusion

Medication-error simulation provides pharmacy learners and practitioners with controlled opportunities to recognize, investigate, communicate about, and respond to safety-critical problems. The evidence supports measurable gains in knowledge, confidence, error recognition, and performance across several simulation configurations.

The strength of those findings depends on how performance is assessed and on how far the outcome lies from the training environment. Most available evidence concerns immediate learning or performance within simulation, with some evidence of delayed or changed-context generalization. Direct evidence of transfer into routine pharmacy work is sparse and methodologically fragile, and patient-level medication-safety effects have not been established.

Accordingly, simulation should be understood as a potentially valuable component of medication-safety preparation whose educational outcomes are better demonstrated than its downstream effects on routine-practice safety. Stronger claims will require validated assessment, longitudinal workplace follow-up, and outcomes capable of testing the full pathway from simulated performance to safer pharmacy practice.

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