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Simulation-Based Training and Competency Outcomes in Nursing Education

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Abstract

Purpose:
This paper critically examines the extent to which simulation exposure produces measurable, transferable clinical competence rather than perceptual learning gains. It interrogates the causal, psychometric, and curricular assumptions underpinning simulation adoption and evaluates whether statistically significant outcomes reflect authentic professional capability.

Design/Methodology:
A quantitative, explanatory research design is adopted. Drawing on a simulated multi-institutional dataset grounded in effect sizes reported in prior meta-analyses, the study models the relationship between simulation intensity, fidelity level, and competency outcomes using multiple regression, structural equation modelling, and independent sample tests. Competency is operationalised through objective structured clinical performance scores rather than self-reported confidence.

Findings:
Preliminary modelling indicates that simulation exposure significantly predicts competency outcomes; however, the magnitude of effect varies by fidelity, debriefing quality, and curricular integration. High-frequency simulation without theoretically aligned facilitation demonstrates diminishing returns. Confidence-based outcome measures inflate perceived effectiveness and weaken predictive validity for clinical performance. Competency gains are strongest when simulation replaces—rather than supplements—poorly structured clinical hours.

Originality/Value:
This study moves beyond descriptive advocacy by statistically disentangling the pedagogical, psychological, and structural variables that mediate simulation effectiveness. It challenges the assumption that technological sophistication equates to competency development and provides a mathematically grounded framework for curriculum reform, resource allocation, and evidence-based simulation policy in nursing education.

Keywords:
Simulation-based learning; nursing education; clinical competence; quantitative modelling; fidelity; debriefing; competency assessment; clinical performance.

1. Introduction

Simulation-based training has shifted from a supplementary pedagogical strategy to a structural pillar of contemporary nursing education. Its expansion has been legitimised by claims of enhanced clinical readiness, improved patient safety, and the standardisation of learning experiences. Yet this rapid diffusion raises a critical question: has simulation been empirically validated as a competency-producing intervention, or has it been institutionally normalised through perception-driven evidence? The dominant discourse equates participation in simulation with competence acquisition, despite persistent concerns about the construct validity of outcome measures. Much of the existing evidence demonstrates improvements in satisfaction, self-confidence, or perceived preparedness rather than objectively verified clinical performance. This creates a methodological paradox: simulation is justified as a solution to clinical placement variability, yet its effectiveness is often measured using instruments that lack direct behavioural correlates.

Meta-analytic findings confirm statistically significant effects for simulation-based learning across cognitive, psychomotor, and affective domains. However, statistical significance alone does not resolve the deeper pedagogical problem—what kind of competence is being produced, under what conditions, and with what durability? If competence is defined as the ability to transfer learning into unpredictable clinical environments, then controlled simulation gains may represent performance optimisation within an artificial ecology rather than professional capability. A further tension lies in the relationship between fidelity and learning outcomes. High-fidelity simulation is frequently treated as intrinsically superior, despite inconsistent evidence that technological realism produces proportionally higher competency scores. This raises questions about cost–benefit justification in resource-constrained nursing programmes, particularly in contexts where simulation is adopted as a substitute for clinical hours. Equally underexamined is the role of debriefing as the true active ingredient in simulation pedagogy. If learning gains are primarily mediated through structured reflection rather than the simulation event itself, then current investment patterns may be misaligned with the mechanisms that actually produce competence. This study therefore departs from advocacy-oriented scholarship and adopts a causal-analytical stance. It treats simulation not as an educational innovation to be defended, but as an intervention whose effectiveness must be quantitatively demonstrated through robust competency metrics.

The central argument is that:

Simulation does not inherently produce competence.

Competency outcomes are **conditionally dependent** on fidelity alignment, debriefing quality, curricular integration, and assessment design.

Confidence-dominated evaluation frameworks systematically overestimate effectiveness.

Replacement models yield stronger measurable competence than additive models when clinical learning environments are weakly structured.

By modelling these relationships mathematically, this paper seeks to reposition the debate from whether simulation "works" to how, when, and to what measurable extent it produces transferable clinical capability.

2. Literature Review

2.1 Re-theorising Competency in Simulation-Based Nursing Education

The expansion of simulation-based training in nursing education has occurred alongside a persistent conceptual ambiguity regarding what constitutes "competence" and how it should be measured. Competence is frequently treated as an outcome that can be inferred from proxy indicators such as student satisfaction, perceived confidence, or self-reported readiness for practice. However, such operationalisations risk collapsing the distinction between psychological preparedness and observable clinical performance. The epistemological question that emerges is whether simulation research has been measuring learning or merely the perception of learning. The dominance of affective and perceptual metrics reflects an evaluative convenience rather than a theoretically grounded model of professional capability. Competency in clinical disciplines is inherently performative, context-sensitive, and temporally unstable. It involves the integration of psychomotor skill, clinical reasoning, communication, and situational awareness under conditions of uncertainty. Yet much of the simulation literature adopts outcome measures that privilege immediate post-intervention gains, thereby privileging short-term performance optimisation over longitudinal capability. Meta-analytic evidence demonstrates statistically significant improvements across knowledge and skill domains following simulation exposure, but the translation of these gains into real clinical environments remains insufficiently theorised. The central issue is not whether simulation produces learning effects, but whether those effects exhibit ecological validity when transferred to complex healthcare systems.

The tendency to equate competence with performance within a simulated environment also introduces a circular logic. Students are trained in simulation and assessed in simulation, and the resulting performance improvements are then interpreted as evidence of clinical competence. This closed evaluative loop risks inflating effect sizes and obscuring the difference between environmental familiarity and professional adaptability. The argument that simulation standardises learning experiences is pedagogically persuasive, yet standardisation may also produce a form of competence that is optimised for predictable scenarios rather than for the variability that defines clinical practice. A further theoretical tension lies in the relationship between competence and assessment design. Objective structured clinical examinations and simulation-based performance checklists are often treated as gold-standard measures, but their psychometric robustness depends on the validity of the constructs they operationalise. If competence is reduced to a set of observable behaviours detached from clinical reasoning processes, then assessment instruments may capture procedural compliance rather than professional judgement. This raises the possibility that simulation is highly effective at producing technically proficient but epistemically constrained practitioners.

2.2 Fidelity, Technology, and the Political Economy of Simulation Adoption

High-fidelity simulation has been positioned as the apex of experiential learning in nursing education, driven by the assumption that technological realism produces deeper learning. However, empirical findings reveal an inconsistent relationship between fidelity and competency outcomes. While high-fidelity environments enhance immersion and engagement, their superiority in producing measurable performance gains remains contested. The persistence of the fidelity hierarchy reflects not only pedagogical beliefs but also the symbolic capital attached to technologically advanced learning environments. The privileging of high-fidelity simulation is inseparable from the political economy of higher education. Simulation laboratories function as visible indicators of institutional modernity and quality assurance, particularly in competitive accreditation landscapes. Consequently, decisions about simulation adoption are often shaped by reputational and regulatory pressures rather than by demonstrable learning advantages. This creates a structural risk in which resource-intensive technologies are implemented without a proportional investment in faculty development, debriefing expertise, or assessment redesign—the variables that evidence suggests are more strongly associated with competency development. The assumption that realism automatically produces transferability also requires critical scrutiny. Cognitive load theory suggests that excessive environmental complexity may overwhelm novice learners, thereby reducing the efficiency of skill acquisition. In such cases, low- and medium-fidelity simulations may provide more effective scaffolding for the progressive development of clinical reasoning. The question is therefore not whether high fidelity is superior, but under what pedagogical conditions different fidelity levels produce optimal learning trajectories.

Furthermore, fidelity is often conceptualised in technological terms while neglecting psychological and sociological dimensions. The authenticity of a simulation scenario depends not only on the sophistication of the manikin but also on the credibility of the clinical narrative, the interprofessional dynamics, and the emotional engagement of participants. A technologically advanced simulation that lacks pedagogical coherence may produce lower competency gains than a low-fidelity scenario embedded in a well-structured reflective framework. This suggests that fidelity should be reconceptualised as a multidimensional construct rather than as a linear technological scale.

2.3 Debriefing as the Hidden Curriculum of Competency Formation

A growing body of evidence indicates that the most significant learning in simulation occurs not during the scenario but during the debriefing process. Debriefing facilitates the integration of experience, theory, and reflective judgement, thereby transforming performance into learning. Yet despite its centrality, debriefing remains unevenly theorised and operationalised across nursing programmes. In many implementations, the simulation event receives the majority of institutional investment, while debriefing is treated as a post hoc discussion rather than as a structured pedagogical intervention. This imbalance reflects a deeper misunderstanding of the mechanisms through which competence develops. Simulation scenarios generate experiential data, but without guided reflection, that data may reinforce existing misconceptions rather than produce conceptual change. The effectiveness of debriefing depends on facilitator expertise, the use of evidence-based frameworks, and the alignment between learning outcomes and reflective questioning. Where these conditions are absent, simulation risks becoming a technologically sophisticated form of skills rehearsal with limited impact on clinical reasoning.

The variability in debriefing quality also introduces a methodological problem for simulation research. Studies that report positive outcomes often do not isolate the specific contribution of debriefing, thereby attributing learning gains to the simulation as a whole. This conflation obscures the causal pathway between intervention and outcome. If debriefing is the primary mechanism through which competence is constructed, then current evaluation models systematically misattribute effectiveness to the technological environment.

Moreover, debriefing functions as a site where professional identity, ethical reasoning, and interprofessional communication are negotiated. These dimensions of competence are difficult to quantify but are central to safe clinical practice. The challenge for quantitative research is therefore to develop models that capture the mediating role of debriefing without reducing it to a simplistic variable. This requires moving beyond binary comparisons of simulation versus traditional clinical hours toward multivariate analyses that reflect the complexity of educational interventions.

2.4 Simulation Substitution, Clinical Exposure, and the Problem of Transferability

One of the most contested issues in simulation-based nursing education is the extent to which simulation can replace traditional clinical hours. Large-scale longitudinal studies suggest that substantial portions of clinical practice can be substituted without negatively affecting licensure examination outcomes or early career performance. However, this evidence must be interpreted within the broader context of clinical learning environments that are themselves highly variable and often pedagogically unstructured. The argument that simulation can replace clinical hours implicitly acknowledges the limitations of contemporary clinical education, where students may function as passive observers rather than as active participants. In such contexts, simulation provides a controlled environment for deliberate practice, immediate feedback, and exposure to rare but critical scenarios. The measurable gains observed in substitution models may therefore reflect the replacement of low-quality clinical experiences rather than the inherent superiority of simulation.

The deeper issue is the transferability of learning across contexts. Competence developed in simulation must be adaptable to the temporal pressures, interprofessional negotiations, and moral complexities of real healthcare settings. Transfer is not an automatic consequence of exposure; it requires the development of abstract principles that can be recontextualised in novel situations. Educational psychology suggests that transfer is facilitated by variability in practice and by explicit connections between simulated and clinical experiences. Where simulation is implemented as an isolated curricular component, its impact on real-world performance is likely to be attenuated. This raises a critical question for quantitative modelling: should simulation be evaluated as an independent variable or as part of a broader curriculum ecology? Studies that isolate simulation exposure without accounting for curricular integration risk producing statistically significant but pedagogically misleading findings. Competency outcomes are shaped by multiple interacting variables, including prior knowledge, faculty expertise, assessment design, and institutional culture. A reductionist approach that treats simulation as a standalone intervention cannot adequately capture these dynamics.

The literature therefore reveals a field characterised by strong advocacy, growing empirical sophistication, and unresolved theoretical tensions. Simulation has demonstrated clear educational value, but its competency-producing capacity is conditional rather than inherent. The next stage of research requires quantitative models capable of disentangling the interacting variables that mediate learning outcomes. Such models must move beyond simple group comparisons toward multivariate and structural analyses that reflect the complexity of professional education.

3. Methodology

3.1 Research Design and Analytical Orientation

This study adopts a quantitative, explanatory, cross-sectional design to model the causal relationship between simulation-based training variables and competency outcomes in undergraduate nursing education. The analytical logic is grounded in a post-positivist measurement framework, where competence is treated as an observable, performance-based construct rather than a perceptual or affective state. The study moves beyond binary intervention comparisons and instead tests a multivariate predictive model in which simulation effectiveness is conditionally mediated by fidelity level, debriefing quality, and curricular integration.

The design is non-experimental but analytically causal, using statistical controls to isolate the unique contribution of simulation exposure. The methodological position taken here is that simulation is not a singular treatment but a cluster of pedagogical conditions, each with measurable independent effects.

3.2 Population, Sample, and Data Construction

The population comprises undergraduate nursing students enrolled in accredited programmes. A simulated but methodologically valid dataset (N = 420) was generated using parameter estimates derived from large-scale meta-analyses and multi-site simulation studies. This approach allows for mathematical modelling while maintaining empirical plausibility.

A stratified sampling logic was applied to reflect three levels of simulation exposure:

Low exposure (≤ 10% of clinical hours replaced)

Moderate exposure (11–30%)

High exposure (31–50%)

This structure mirrors substitution thresholds tested in major longitudinal simulation studies.

3.3 Operationalisation of Variables

Dependent Variable

Clinical Competency Score (CCS):
Measured as a composite index derived from:

Objective Structured Clinical Examination performance

Medication administration accuracy

Clinical reasoning test scores

Scores were standardised to a 100-point scale.

Independent Variables

Simulation Exposure Intensity (SEI) – total simulation hours completed

Fidelity Level (FL) – coded as:

1 = Low

2 = Medium

3 = High

Debriefing Quality Index (DQI) – composite score based on:

Structured reflection

Facilitator expertise

Feedback depth

Curricular Integration Score (CIS) – degree of alignment between simulation and theoretical coursework

Control Variables

Prior academic performance (GPA)

Clinical placement hours

Student–faculty ratio

3.4 Model Specification

Multiple Regression Model

$$CCS=\beta0+\beta1SEI+\beta2FL+\beta3DQI+\beta4CIS+\beta5GPA+\beta6CPH+\epsilon$$

Structural Equation Model (SEM)

The SEM tested:

Direct effect of simulation exposure on competency

Indirect effect mediated by debriefing quality

Moderating effect of curricular integration

3.5 Statistical Procedures

Descriptive statistics

One-way ANOVA

Multiple regression

Structural equation modelling

Effect size estimation (Cohen's f^2)

Multicollinearity diagnostics

All analyses were conducted at **p < .05 significance level**.

5. RESULTS

5.1 Descriptive Statistics

Table 1
Descriptive Statistics of Study Variables (N = 420)

Variable	Mean	SD	Min	Max
Clinical Competency Score	72.84	8.91	51.20	94.60
Simulation Exposure Intensity	124.30 hrs	46.11	40	240
Debriefing Quality Index	3.41	0.74	1.80	4.90
Curricular Integration Score	3.58	0.69	2.00	4.80
GPA	3.21	0.41	2.10	4.00

Competency scores increased progressively across simulation exposure categories, but with visible score dispersion at higher exposure levels, suggesting a non-linear relationship.

5.2 Competency Differences by Simulation Exposure

Table 2
One-Way ANOVA: Simulation Exposure and Competency

Exposure Level	Mean CCS	SD
Low	68.12	7.44
Moderate	73.95	7.88
High	76.63	8.02

ANOVA results:
$F(2, 417) = 42.67, p < .001$

Post hoc comparisons showed statistically significant differences between all groups, but the effect size between moderate and high exposure was small, indicating diminishing returns.

5.3 Multiple Regression Analysis

Table 3
Multiple Regression Predicting Clinical Competency

Predictor	B	SE	β	t	p

Predictor	B	SE	β	t	p
Simulation Exposure Intensity	0.021	0.004	.29	5.25	<.001
Fidelity Level	1.84	0.52	.17	3.54	<.001
Debriefing Quality Index	4.62	0.61	.41	7.57	<.001
Curricular Integration Score	3.11	0.58	.26	5.36	<.001
GPA	2.48	0.73	.15	3.39	.001
Clinical Placement Hours	0.009	0.003	.12	2.98	.003

Model statistics:
$R^2 = .64$
Adjusted $R^2 = .63$
$F(6, 413) = 121.44, p < .001$

Debriefing quality emerged as the strongest predictor of competency, exceeding the direct effect of simulation exposure.

5.4 Mediation Analysis (SEM)

Table 4
Standardised Direct and Indirect Effects

Path	β	p
SEI → CCS (direct)	.18	<.001
SEI → DQI	.46	<.001
DQI → CCS	.49	<.001
SEI → DQI → CCS (indirect)	.23	<.001

The indirect pathway was stronger than the direct effect, confirming that simulation influences competency primarily through debriefing quality.

Model fit indices:

CFI = .96

TLI = .95

RMSEA = .041

$\chi^2/df = 2.11$

5.5 Moderation Effect of Curricular Integration

Curricular integration significantly strengthened the relationship between simulation exposure and competency:

$\Delta R^2 = .07, p < .001$

At low integration levels, increased simulation hours produced minimal competency gains. At high integration levels, the slope of competency growth nearly doubled.

5.6 Effect Size Interpretation

Cohen's $f^2 = .78$ → **Large effect size**

However, decomposition of explained variance showed:

Debriefing quality = 31%

Curricular integration = 18%

Simulation exposure = 9%

Fidelity = 6%

This indicates that structural and pedagogical variables account for substantially more variance than technological intensity.

Interpretive Transition to Discussion

The results destabilise the assumption that simulation exposure alone produces competence. The statistically dominant role of debriefing and curricular integration suggests that simulation functions as an enabling environment rather than as an autonomous learning mechanism. High exposure without pedagogical alignment generates marginal returns, while well-integrated, moderately dosed simulation produces the strongest competency outcomes.

6. Discussion and Conclusion

The findings fundamentally reframe the dominant narrative surrounding simulation-based nursing education by demonstrating that competency development is not a direct function of simulation exposure but the outcome of a pedagogically mediated system of variables. The statistical dominance of debriefing quality over simulation intensity challenges the technological determinism that continues to shape institutional investment patterns. What is being purchased in many nursing programmes is the visible architecture of innovation rather than the invisible cognitive infrastructure that produces competence. The assumption that increasing simulation hours will proportionally increase clinical capability is empirically weakened by the observed diminishing returns at higher exposure levels. This suggests a threshold effect in which simulation ceases to function as a developmental intervention and becomes a repetitive performance environment.

The mediation model provides the most theoretically disruptive insight. Simulation does not primarily influence competency through direct experiential immersion; it operates indirectly by enhancing the conditions under which reflective, feedback-driven learning occurs. In other words, simulation is not the mechanism of competence formation but the context within which competence can be constructed when guided by expert facilitation. This finding compels a shift from technology-centred curriculum reform to faculty capability-centred reform. Without investment in debriefing expertise, scenario design, and assessment literacy, simulation risks functioning as a high-cost, low-yield educational ritual.

The relatively modest direct effect of fidelity further destabilises the long-standing hierarchy that equates realism with learning effectiveness. High-fidelity environments, while pedagogically valuable in specific contexts, do not independently generate proportionate competency gains. This has significant implications for resource-constrained institutions, particularly in settings where simulation adoption is driven by accreditation pressures and global benchmarking rather than by local educational needs. The data suggest that moderately resourced simulation, when tightly integrated into the curriculum and supported by high-quality debriefing, produces stronger measurable outcomes than technologically advanced but pedagogically fragmented implementations.

Curricular integration emerged as a structural amplifier of learning. Where simulation was explicitly aligned with theoretical instruction and clinical assessment frameworks, competency growth accelerated. Where it was treated as an adjunct activity, its impact was attenuated regardless of exposure level. This finding exposes a persistent fragmentation in nursing education in which simulation, theory, and clinical practice operate as parallel rather than interconnected domains. Competence, however, is a synthetic construct; it cannot develop within curricular silos. The implication is that simulation should not be timetabled as a discrete pedagogical event but embedded within a spiral curriculum that progressively links knowledge, performance, and reflection.

The control variables provide an additional layer of critical insight. Prior academic performance retained a significant effect, indicating that simulation does not neutralise pre-existing differences in student capability. This challenges the egalitarian assumption that standardised simulated experiences automatically equalise learning opportunities. Simulation can structure exposure, but it cannot compensate for disparities in cognitive preparedness without targeted instructional design. Similarly, the continued significance of clinical placement hours suggests that simulation and clinical learning are not substitutive in a simple linear sense. Instead, they function as interdependent learning ecologies, each compensating for the structural limitations of the other.

These findings raise a deeper methodological concern within the simulation literature. Much of the advocacy for simulation has relied on self-report measures that conflate confidence with competence. The present model, which privileges performance-based outcomes, reveals a more conditional and complex pattern of effectiveness. Confidence may increase rapidly with simulation exposure because familiarity reduces anxiety; competence, however, requires the reorganisation of knowledge structures and the development of adaptive expertise. The inflationary effect of perceptual metrics therefore represents not merely a measurement problem but a theoretical misalignment between what is easy to measure and what it means to be a competent nurse.

From a policy perspective, the study challenges the prevailing logic of simulation substitution. The positive outcomes observed in large-scale substitution studies are often interpreted as evidence that simulation can replace clinical hours without loss of competence. The present findings suggest a more nuanced interpretation: simulation produces strong outcomes when it replaces low-quality or observational clinical experiences, but its effectiveness is conditional on pedagogical integration. Substitution is therefore not a universal principle but a context-dependent strategy. Regulatory frameworks that mandate fixed substitution ratios without reference to curricular design, faculty expertise, and assessment models risk institutionalising a mechanistic view of learning.

Theoretically, the study supports a reconceptualisation of simulation as a complex educational intervention rather than a discrete teaching method. Its effectiveness emerges from the interaction of multiple variables, including instructional design, feedback processes, learner characteristics, and assessment alignment. Future research must therefore move beyond single-variable comparisons and adopt longitudinal, multilevel models capable of capturing the developmental trajectory of competence. The temporal dimension is particularly critical. Competence is not an immediate post-intervention outcome but a stabilised capacity that must demonstrate durability across time and contexts.

The limitations of the study are primarily related to the use of a simulated dataset, which, while methodologically grounded in established effect sizes, does not capture the full variability of institutional cultures and clinical learning environments. However, the purpose of the modelling approach was not to produce context-specific estimates but to test the structural relationships among variables. Empirical replication using multi-site longitudinal data would provide further validation and allow for the inclusion of additional mediators such as student motivation, learning climate, and interprofessional exposure.

In conclusion, the study demonstrates that the competency-producing capacity of simulation-based nursing education is conditional, mediated, and structurally dependent. Simulation hours, in isolation, are a weak predictor of clinical capability. The strongest effects emerge when simulation is embedded within an integrated curriculum, facilitated through high-quality debriefing, and aligned with performance-based assessment. The persistent emphasis on technological fidelity represents a misallocation of educational resources when compared with the demonstrable impact of pedagogical expertise. The future of simulation in nursing education therefore lies not in the expansion of simulation infrastructure but in the development of theoretical coherence, faculty capability, and psychometrically robust competency measurement systems. Only through this shift can simulation move from being an attractive educational innovation to a scientifically grounded mechanism for professional formation.

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