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# Immersive Virtual Reality in Undergraduate Critical Care Nursing Education: A Pragmatic Three-Cohort Quasi-Experimental Evaluation of Perceived Simulation Effectiveness and Clinical Learning Needs

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## Abstract

# Background

Preparing undergraduate nurses for high-acuity practice requires educational approaches that allow safe rehearsal of complex clinical situations, yet evidence from routine programme delivery remains mixed when immersive virtual reality (VR) is compared with established teaching approaches.

# Methods

A post-test-only, non-randomised, between-cohort quasi-experimental design was used with three intact undergraduate nursing cohorts within one programme in the United Arab Emirates (N = 150; n = 50 per cohort): a traditional laboratory cohort in Fundamentals of Nursing, a face-to-face simulation-laboratory cohort in Medical-Surgical Nursing, and an immersive VR cohort in Critical Care Nursing using a head-mounted display. Immediately after the scheduled session, students completed the Simulation Effectiveness Tool-Modified (SET-M) and the Clinical Learning Environment Comparison Survey (CLECS 2.0). One-way analysis of variance with Tukey post-hoc testing compared cohort means.

# Results

SET-M scores differed significantly across cohorts ($F(2,147) = 16.49$, $p < .001$, $\eta^2 = .18$), with the VR cohort scoring higher than both the simulation-laboratory cohort and the traditional cohort. CLECS 2.0 total scores did not differ significantly ($F(2,147) = 0.35$, $p = .708$).

# Conclusions

Within this pragmatic phased implementation, the immersive VR cohort reported higher perceived simulation effectiveness, particularly in the critical care-oriented cohort, whereas perceived fulfilment of clinical learning needs was comparable across conditions. Findings should be interpreted cautiously because cohorts differed by course and programme level and all outcomes were self-reported. Future research should reduce cohort-level confounding, include objective performance and clinical-reasoning outcomes, and examine implementation, usability, and transfer beyond the immediate session.

## 1 Introduction

Simulation-based learning is a core strategy in undergraduate nursing education because it allows students to practise psychomotor skills, communication, clinical reasoning, and decision making without exposing patients to unnecessary risk. This need is especially acute in high-acuity and critical care contexts, where learners must interpret rapidly changing information, prioritise care, and act safely under

pressure. As immersive head-mounted display technologies have become more accessible, VR has moved from experimental use toward practical curricular integration in health professions education.

Immersive VR is attractive because it can increase presence, interactivity, and experiential engagement. However, educational value cannot be inferred from novelty alone. Evidence syntheses in nursing and health professions education report promising effects on satisfaction, confidence, and selected learning outcomes, but they also identify substantial heterogeneity in design quality, implementation fidelity, facilitation, debriefing, and outcome measurement [1, 2, 3]. Broader educational technology reviews similarly conclude that immersive tools are most effective when technology, pedagogy, and learner support are aligned, rather than when immersion is treated as an end in itself [4, 5].

In critical care-oriented education, the appeal of immersive VR lies not simply in novelty but in the possibility of offering structured exposure to high-acuity scenarios when access to specialised placements, high-fidelity resources, or tightly scheduled simulation spaces is constrained. From an educational leadership and technology-enhanced learning perspective, decisions about VR adoption therefore depend on more than learner enthusiasm. They also depend on organisational readiness, faculty preparation, device management, infection-control processes, psychological safety, data governance, usability, and the extent to which VR complements rather than replaces existing simulation infrastructure. These issues are relevant not only to nursing and medical education, but also to educational technology and implementation scholarship concerned with how digital learning environments function under real programme conditions [6].

While existing literature highlights the promise of VR, fewer studies have evaluated phased implementation across intact undergraduate nursing cohorts under routine programme conditions, and many previous studies have examined VR in tighter experimental settings or in isolation from existing curricular modalities. To address this practice-oriented gap, we evaluated a phased implementation of three teaching modalities across three pre-scheduled undergraduate nursing cohorts within one semester in the United Arab Emirates. The immersive VR condition was situated in a Critical Care Nursing course and was compared with existing traditional-laboratory teaching in Fundamentals of Nursing and face-to-face simulation-laboratory teaching in Medical-Surgical Nursing. The primary objective was to compare perceived simulation effectiveness across the three conditions. The secondary objective was to compare perceived fulfilment of clinical learning needs. Because the cohorts differed by course and programme level, the study was designed to provide a pragmatic cross-cohort comparison of learner perceptions under routine programme conditions rather than an isolated estimate of modality-specific causal effects.

# 2 Methods

### Design and reporting approach

This study used a post-test-only, non-randomised, between-cohort quasi-experimental design. Three intact cohorts were compared after a phased curricular implementation in which each course used one

planned teaching modality. Because students were grouped by course and programme level rather than by random allocation, the design supports a pragmatic cross-cohort comparison of learner perceptions but does not isolate modality effects from cohort- or course-level influences. The study is reported with explicit attention to intervention delivery, comparison conditions, timing, outcome selection, and design limitations, consistent with transparent reporting principles for non-randomised evaluations [7, 8].

**Setting, participants, and educational conditions**

The evaluation was conducted at a public higher-education institution in the United Arab Emirates between June and December 2023. All undergraduate nursing students enrolled in the three targeted course cohorts were invited to participate. Eligibility criteria were enrolment in one of the selected courses and attendance at the scheduled learning session. Participation was voluntary and based on written informed consent.

The three cohorts reflected a staged implementation across the curriculum: (1) a traditional laboratory approach in a Fundamentals of Nursing course, (2) a face-to-face simulation-laboratory approach in a Medical-Surgical Nursing course, and (3) an immersive VR approach in a Critical Care Nursing course. A total of 163 questionnaires were returned. Thirteen responses lacked complete cohort assignment and were excluded. The final analytic sample comprised 150 students, with 50 students in each cohort. All participants were female, reflecting programme enrolment during the study period, and no participant reported prior VR simulation experience. Because the VR condition was situated in Critical Care Nursing, the evaluation is particularly relevant to undergraduate preparation for high-acuity practice; however, the comparison remains cross-cohort and should not be interpreted as an isolated estimate of critical care competence.

**VR intervention and comparison conditions**

The immersive VR condition was delivered using a standalone head-mounted display (Meta/Oculus Quest 2) and a commercial nursing simulation platform (Simulation Learning System with VR; SimX). To improve reproducibility, the standard session workflow is reported explicitly. Students first received orientation to the headset and controls (approximately 5 minutes), then participated in an interactive VR scenario (approximately 15–20 minutes), followed by a facilitated debrief (approximately 10–15 minutes). Questionnaire measures were completed immediately after the session.

Facilitation and debriefing in the VR condition were led by nursing faculty using structured reflective discussion consistent with recognised simulation best-practice standards, including psychological safety, guided reflection, and explicit linkage to learning outcomes [9, 10]. The two comparator conditions were analysed as naturally occurring curricular conditions rather than as separately protocolised interventions. The traditional-laboratory cohort completed the scheduled course laboratory session within the Fundamentals course, and the simulation-laboratory cohort completed the scheduled face-to-face simulation session within the Medical-Surgical course; both groups then completed the same post-session survey packet immediately after the scheduled session. Because the evaluation was

embedded in routine programme delivery, detailed session-level fidelity descriptors for these non-VR comparator conditions were not prospectively captured beyond modality type, course context, and immediate survey timing. This constraint is reported explicitly because it limits fine-grained attribution of observed differences to modality alone.

**Measures**

The study used previously published instruments rather than a questionnaire developed specifically for this study. The measured outcomes were assessed using the Simulation Effectiveness Tool-Modified (SET-M), the Clinical Learning Environment Comparison Survey 2.0 (CLECS 2.0), and the General Self-Efficacy Scale (GSE-10), and the relevant source references are provided below.

Perceived simulation effectiveness was measured using the Simulation Effectiveness Tool-Modified (SET-M). The SET-M contains 19 items rated on a 3-point scale, producing a total score range of 19–57, with higher scores indicating greater perceived effectiveness of the learning experience. The instrument has reported evidence of content alignment with simulation standards and acceptable psychometric performance in nursing education research [11, 12]. In this study, the SET-M total score was used because the analytic aim was an overall programme-level comparison of perceived simulation effectiveness across three naturally occurring educational conditions rather than domain-level profiling, and use of a prespecified total score avoided unnecessary multiplicity in a modest sample.

Perceived fulfilment of clinical learning needs was measured using the Clinical Learning Environment Comparison Survey (CLECS 2.0). CLECS 2.0 contains 29 items rated on a 4-point scale, producing a total score range of 29–116, with higher scores indicating stronger perceived fulfilment of learning needs across relevant clinical-learning domains. Prior work supports its validity and reliability for comparing learning environments in undergraduate nursing education [13, 14]. As with SET-M, the analysis focused on the prespecified CLECS 2.0 total score because the study question concerned overall perceived fulfilment of clinical learning needs across educational conditions rather than subscale-level diagnostic interpretation.

General self-efficacy was captured using the 10-item General Self-Efficacy Scale (GSE-10) and was treated strictly as a cohort characteristic rather than as an immediate intervention outcome because it represents a relatively stable self-belief construct [15]. Accordingly, GSE-10 is reported descriptively to characterise cohort context and programme progression and was not included among the primary inferential outcome comparisons.

**Procedure**

Surveys were administered immediately after completion of each scheduled educational session, including debriefing where applicable, to reduce recall bias and to anchor responses to the learning experience just completed. Students received a brief standardised explanation of the study purpose, the

voluntary nature of participation, and confidentiality procedures before completing the questionnaires. Data were collected anonymously and analysed at the aggregate level.

### Statistical analysis

Descriptive statistics were used to summarise participant characteristics and outcomes by cohort. One-way analysis of variance (ANOVA) compared cohort means on the two prespecified outcome variables: SET-M total scores and CLECS 2.0 total scores. Tukey's honestly significant difference test was used for pairwise comparisons when the omnibus test was significant. Effect size was reported using eta-squared ($\eta^2$). Given the equal cohort sizes, ANOVA was considered appropriate for these planned comparisons. Because the design was post-test-only and non-randomised, results were interpreted conservatively and not as evidence of a modality-specific causal effect. GSE-10 was intentionally excluded from the inferential outcome model because it was used to describe cohort context rather than to estimate an immediate educational effect.

### Ethical considerations

Ethical approval was obtained from the Research Ethics and Integrity Committee (REIC) of the Higher Colleges of Technology, United Arab Emirates (Proposal No. 219; notification dated 16 June 2023). Participation was voluntary, and written informed consent was obtained before questionnaire completion. Data were collected anonymously and reported in aggregate.

## 3 Results

### Participant characteristics

Participant characteristics are summarised in Table 1. Age and grade point average were similar across cohorts. All participants were female, none reported prior VR simulation experience, and the cohorts represented three different courses and programme levels. GSE-10 scores were higher in the later programme cohorts, but these values are presented descriptively to characterise cohort context rather than as intervention outcomes.

Table 1
Participant characteristics by cohort.

| Characteristic | Traditional (n = 50) | Simulation lab (n = 50) | VR (n = 50) | Total (N = 150) |
|---|---|---|---|---|
| Course cohort | Fundamentals of Nursing | Medical-Surgical Nursing | Critical Care Nursing | N/A |
| Age, years, mean (SD) | 20.18 (0.75) | 20.20 (0.76) | 20.44 (0.54) | 20.27 (0.69) |
| Female, n (%) | 50 (100.0%) | 50 (100.0%) | 50 (100.0%) | 150 (100.0%) |
| GPA, mean (SD) | 3.01 (0.41) | 3.01 (0.39) | 3.11 (0.33) | 3.04 (0.38) |
| Prior VR simulation experience, n (%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| GSE-10 total, mean (SD) | 19.00 (3.55) | 30.70 (3.36) | 32.80 (2.18) | 27.50 (7.27) |

*GSE-10 is reported descriptively to characterise cohort context and programme progression rather than as an immediate intervention outcome.*

**Perceived simulation effectiveness**

SET-M total scores differed significantly across cohorts ($F(2,147) = 16.49$, $p < .001$, $\eta^2 = .18$). The immersive VR cohort reported the highest perceived simulation effectiveness. Tukey post-hoc testing indicated that the VR cohort scored significantly higher than the simulation-laboratory cohort (mean difference = 3.24, $p < .001$) and the traditional cohort (mean difference = 4.32, $p < .001$). The simulation-laboratory and traditional cohorts did not differ significantly ($p = .344$).

**Perceived fulfilment of clinical learning needs**

CLECS 2.0 total scores did not differ significantly across cohorts ($F(2,147) = 0.35$, $p = .708$). Across the three conditions, students therefore reported broadly comparable perceptions of how well their immediate learning environment addressed clinical learning needs. This pattern suggests that the broader perceived fulfilment of clinical learning needs may have been less sensitive to a single-session modality contrast than the more simulation-focused perceptions captured by SET-M. Outcome comparisons for all cohorts are summarized in Table 2.

Table 2
Outcome comparisons by cohort.

| Outcome (scale range) | Traditional mean (SD) | Simulation lab mean (SD) | VR mean (SD) | F(2,147) | p | η² |
|---|---|---|---|---|---|---|
| SET-M total (19–57) | 40.86 (4.45) | 41.94 (3.60) | 45.18 (3.63) | 16.49 | < .001 | 0.18 |
| CLECS 2.0 total (29–116) | 61.46 (7.35) | 61.06 (6.14) | 62.14 (6.12) | 0.35 | 0.708 | 0.00 |

*Tukey post-hoc testing for SET-M showed VR > simulation lab and VR > traditional; simulation lab and traditional did not differ significantly.*

# 4 Discussion

### Principal findings

In this pragmatic three-cohort evaluation, the immersive VR cohort reported higher perceived simulation effectiveness than the simulation-laboratory cohort and the traditional laboratory cohort. Because the VR cohort was situated in a Critical Care Nursing course, the findings are particularly relevant to high-acuity undergraduate nursing education, but they should not be interpreted as modality-specific causal estimates. In contrast, perceived fulfilment of clinical learning needs did not differ significantly across conditions. Taken together, the findings suggest that immersive VR can be integrated into undergraduate nursing programmes in ways that are perceived positively by learners under routine teaching conditions.

### Interpretation in relation to prior literature

The SET-M findings are broadly consistent with prior reviews reporting that immersive VR can enhance engagement, satisfaction, and perceived learning in nursing and health professions education [1, 2, 3]. The present study adds a pragmatic perspective by comparing VR with two existing teaching modalities embedded in normal curriculum delivery, rather than evaluating VR in isolation.

The absence of cohort differences in CLECS 2.0 totals warrants careful interpretation. One possibility is that students perceived core clinical-learning functions as being addressed across all three teaching environments, despite differences in perceived simulation effectiveness. Another possibility is that a post-session cross-cohort comparison is less sensitive to nuanced differences in learning-environment fulfilment than designs in which the same learners experience multiple environments over time. In other words, students may judge the immediate simulation experience and the broader fulfilment of clinical learning needs through partially different frames of reference; the former may respond more readily to immersion and interaction design, whereas the latter may remain anchored to wider expectations about curriculum, support, and clinical preparation. The findings therefore support a differentiated

interpretation: immersive VR may strengthen the perceived effectiveness of the learning experience without necessarily producing immediate differences in broader perceived clinical-learning needs.

**Implications for nursing, medical education, and intensive care education**

For nursing and medical education leaders, the results support careful consideration of immersive VR as a complement to existing simulation infrastructure rather than as a wholesale replacement for simulation-laboratory teaching. This is especially relevant to intensive care education and other high-acuity contexts, where access to specialised clinical placements, complex equipment, and resource-intensive simulation spaces may be constrained. Under such conditions, immersive VR may offer a practical way to extend exposure to high-pressure scenarios while preserving structured facilitation and reflective debriefing. However, implementation quality remains central. Effective adoption requires faculty preparation, scenario selection aligned with learning outcomes, structured debriefing, device hygiene and infection-control procedures, technical support, and clear attention to learner psychological safety. These are leadership and governance issues as much as they are pedagogical ones.

The study also carries an ethical implementation message. Introducing immersive technologies into health-professions education should be guided by equitable access, informed participation, and avoidance of unnecessary distress or exclusion. A technology that is exciting but poorly governed can undermine, rather than strengthen, educational quality.

**Implications for technology-enhanced learning and educational technology**

From a technology-enhanced learning perspective, the study contributes evidence from a real programme implementation in which immersive technology was embedded in curriculum delivery rather than tested only as a laboratory prototype. This is relevant to educational technology scholarship because the value of immersive systems depends not only on content realism but also on usability, implementation readiness, facilitation design, and how well the technology fits the instructional context. Prior work has highlighted organisational readiness as an important determinant of successful technology adoption in nursing education [6], and the present findings reinforce the need to evaluate immersive systems as sociotechnical learning environments rather than as devices alone. This is especially important in high-acuity teaching contexts, where digital learning tools must support safe preparation without encouraging overclaiming about competence that has not been objectively assessed.

Future work in this area would benefit from combining perception measures with platform-level interaction data, usability indicators, accessibility considerations such as motion-sickness mitigation, and learning-analytics approaches that support feedback and instructional decision making. In critical care-oriented education, future studies should also examine clinical reasoning under pressure, cognitive load, teamwork processes, and transfer to assessed performance rather than relying only on post-session perceptions.

### Strengths and limitations

This study has several strengths. It reports a field implementation under routine programme conditions, uses equal cohort sizes, applies established instruments, and compares immersive VR with two existing educational approaches rather than with a no-exposure control. These features improve practical relevance for programmes considering adoption. The manuscript also reports the design and intervention conditions cautiously and transparently, which is important for interpreting a non-randomised educational evaluation.

The study also has important limitations. First, the cohorts were intact and differed by course and programme level, so observed differences cannot be attributed solely to modality. Second, all outcomes were self-reported, which limits inference about objective knowledge or skill performance. Third, the design was post-test-only, so within-student change could not be estimated. Fourth, the study was conducted at a single institution with an all-female sample, which may limit transferability to other settings. Fifth, implementation-fidelity information was stronger for the VR condition than for the non-VR comparator conditions because the evaluation arose from routine programme delivery rather than from a fully protocolised trial. This asymmetry should be considered when interpreting the between-cohort comparisons, because unmeasured differences in session structure, facilitation, or reflective processing may have contributed to the observed pattern. Finally, although GSE-10 was reported for cohort context, it was not used to adjust the primary comparisons because it is entangled with programme progression in this design. These limitations should be considered when interpreting both the magnitude and the generalisability of the findings.

### Future research

Future studies should reduce course-level and cohort-level confounding by using within-course randomised, counterbalanced, or crossover designs where feasible. Objective performance measures, including skills checklists, structured observation, clinical-reasoning indicators, or assessment outcomes, should accompany perception data. Multi-site studies would also strengthen external validity. In addition, implementation-focused work should examine faculty workload, scenario fidelity, learner usability, accessibility, data governance, and cost-effectiveness so that adoption decisions in intensive care education and related high-acuity contexts can be informed by educational, organisational, and technological evidence together.

## 5 Conclusion

In this real-world undergraduate nursing implementation, the immersive VR cohort reported higher perceived simulation effectiveness than the simulation-laboratory and traditional laboratory cohorts, whereas perceived fulfilment of clinical learning needs was comparable across conditions. Because the immersive VR cohort was situated in a Critical Care Nursing course and the comparison involved intact cohorts from different courses and programme levels, the findings should be interpreted as a pragmatic cross-cohort evaluation of learner perceptions rather than as proof of modality-specific superiority. The

main contribution of the study is therefore practical: it shows how immersive VR can be integrated into routine programme delivery in ways that are positively perceived by learners while highlighting the leadership, pedagogical, ethical, and technology-implementation conditions that should shape future adoption and evaluation.

# Declarations

Ethical approval was obtained from the Research Ethics and Integrity Committee (REIC) of the Higher Colleges of Technology, United Arab Emirates (Proposal No. 219; notification dated 16 June 2023). The study was conducted in accordance with the Declaration of Helsinki. Participation was voluntary, and written informed consent was obtained before survey completion.

**Consent for publication:** Not applicable.

**Availability of data and materials:**

The datasets generated and/or analysed during the current study are not publicly available because of institutional data-governance requirements but are available from the corresponding author on reasonable request and subject to institutional approval.

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**Competing interests:** The authors declare that they have no competing interests.

**Use of generative AI:** During manuscript preparation, the authors used a large language model for editorial support in drafting and language refinement under full human review. No AI tool was used to generate study data, perform statistical analyses, or determine participant inclusion or exclusion. The authors reviewed and approved all manuscript content and take full responsibility for the final text.

**Author contributions:**

Conceptualization: S.I., F.A., A.S. Study design and implementation: S.I., A.S., F.A. Data curation: F.A. Formal analysis: A.A., A.K. Writing-original draft: F.A., S.I. Writing-review & editing: S.I., F.A., A.S., A.A., A.K. Supervision: S.I., F.A. All authors read and approved the final manuscript.

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