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Virtual Reality Simulation as a Learning Tool in Nursing Education: Impact on Engagement, Knowledge, and Critical Thinking

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Abstract

Virtual reality simulation (VRS) is a cutting-edge educational approach that offers nursing students immersive and authentic learning experiences beyond what traditional simulation-based education (SBE) with standardized participants can provide. This study examined the impact of four fully immersive VRS scenarios compared to conventional SBE on learning outcomes among vocational and higher education pre-registration nursing students at a Melbourne-based training and further education institute. Using a mixed-methods quasi-experimental design over two academic semesters (2019–2020), 675 students participated, with 393 assigned to the VRS group and 282 to the SBE group. The VRS group demonstrated markedly higher engagement, with 95% of students actively participating compared to an average of 15% in the SBE group. Initial knowledge assessments favored VRS participants ($p < 0.01$), although these differences were not sustained following clinical placements. Students reported that VRS provided realistic clinical scenarios that enhanced their preparedness for practice, despite some technical limitations. Moreover, VRS proved to be more cost-efficient than SBE. Overall, VRS facilitated critical thinking and offered a scalable, effective platform for teaching complex clinical situations in nursing education.

Keywords: Virtual reality simulation, Simulation-based education, Nursing education, Scenario-based learning, Online learning

Introduction

Simulation-based education (SBE) is now widely implemented in pre-registration health professional programs as an evidence-based strategy for practicing clinical skills [1–3]. Immersive, multisensory simulation environments support the development of psychomotor abilities and higher-order cognitive functions [1]. The value of simulation became especially apparent during the COVID-19 pandemic, when virtual learning was required to maintain clinical education [4]. While traditional simulations are effective, they are challenging to scale due to growing student numbers and limited access [5]. Consequently, only a small proportion of students can actively participate in simulations, leaving most as passive observers [5]. Expanding opportunities for authentic, hands-on learning is critical to developing competent and confident practitioners.

Virtual reality (VR) technology represents an innovative tool increasingly adopted in health professions education. VR simulations enable interactive, authentic, standardized, and safe learning experiences [6–8]. Fully immersive three-dimensional VR allows learners to feel physically present in a simulated environment [9–11], enhanced by head-mounted displays or VR glasses [10]. Once developed, VR scenarios can be reused across multiple learners and accessed remotely at any time [6, 7].

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VR also allows students to experiment with decision-making and experience high-risk clinical situations without compromising safety [7]. Limitations include variable realism and immersion [12], high development costs, and the need for time-intensive preparation [6, 7, 13]. Additionally, VR implementation requires reliable internet, appropriate hardware, technology literacy, and preparatory training [7].

Although emerging evidence suggests VR simulation (VRS) can enhance nursing students' knowledge and perceptions of learning [8, 14–16], studies examining its cost-effectiveness remain limited. JasperVR is a fully immersive VR program developed through a collaborative consortium, designed to engage students' visual, auditory, and motion senses in 3D clinical scenarios. Using VR headsets and gaze control, students make decisions that influence patient outcomes, enabling experiential learning in a safe environment.

The aim of this study was to evaluate the educational outcomes of traditional SBE compared to fully immersive VRS for vocational and higher education nursing students at a Melbourne-based training and further education institute.

Research questions

1. How does VRS affect students' knowledge, confidence, and motivation in managing common clinical conditions compared to SBE?
2. What are students' perceptions regarding the usability, efficiency, and effectiveness of VRS?
3. Does VRS increase the number of students who experience immersive simulation learning?
4. Is JasperVR a feasible and economically viable educational approach?

Materials and Methods

A mixed-methods quasi-experimental design was employed to compare learning outcomes between traditional SBE using simulated participants and VRS. Ethical approval was obtained from the Monash University Human Research Ethics Committee (Project ID: 19235), and all participants provided written informed consent.

Materials

JasperVR, delivered through the VirtualU platform, was developed collaboratively to provide a VR-based learning environment. Using 360-degree video and spatial audio technology, JasperVR captured variations and potential outcomes across common clinical scenarios. Students interacted with scenarios via VR headsets and gaze-based controls, selecting pre-determined actions that influenced patient trajectories. Immediate feedback was provided through visualization of the consequences of their decisions, followed by structured debriefing and group discussion after each simulation.

Participants

The study involved students enrolled in the Bachelor and Diploma of Nursing programs at a Training and Further Education Institute between July 2019 and June 2020. Participation was voluntary, with informed consent obtained from all students. Seven distinct cohorts were included **(Table 1)**. Students were pre-organized into small tutorial groups (5–6 students per group), which were randomly assigned to either the control or intervention conditions by an independent organization. Those who did not consent to participate continued with regular teaching activities and were classified as a non-intervention group.

Facilitators

A dedicated team of three experienced facilitators oversaw both control and intervention sessions. Facilitators underwent a one-hour training session focused on effective debriefing techniques and were provided with a structured debriefing guide. Debriefing sessions adhered to the Promoting Excellence and Reflective Learning in Simulation (PEARLS) framework [17].

Simulation scenarios

All participants completed four clinical modules:

1. Managing a verbally aggressive patient
2. Responding to patient deterioration
3. Caring for a patient with cognitive impairment
4. Providing palliative and end-of-life care

Interventions

Control group (Traditional simulation):

Students followed standard curriculum activities, including lectures, tutorials, clinical skills labs, role-plays, and four large-group immersive simulations with standardized patients conducted in the Simulation Centre.

Intervention group (VRS)
Students completed the same core curriculum as the control group, with the four JasperVR modules substituting for the traditional face-to-face immersive simulation sessions.

Implementation
Simulation standards of best practice were applied to both groups [18]. While pre-briefing and debriefing were conducted separately for each group, both followed the PEARLS framework [17].

Pre-briefing
A trained facilitator provided an overview of each module, outlining learning objectives and clinical relevance.

Debriefing
After each session, students participated in structured debriefing to reflect on the scenarios, discuss key clinical concepts, ask questions, and consolidate learning.

VRS delivery
Intervention participants received a JasperVR handbook and VR headset. During the initial session, students installed the VirtualU application on their devices via the institute's Wi-Fi. Technical support was available throughout the study.

VRS modules
1. **Free Exploration:** Students could navigate scenarios independently, make clinical decisions, and revisit modules multiple times to reinforce learning.
2. **Mastery Videos:** Pre-recorded demonstrations by clinical experts highlighted best practices and key skills. These could be accessed individually or incorporated into classroom sessions to illustrate exemplary performance.

Data collection
Data were collected using a combination of quantitative and qualitative methods **(Table 1)**, assessing knowledge acquisition, engagement, and students' perceptions regarding usability, effectiveness, and overall learning experience with the VRS platform.

Table 1. Protocol for between group comparisons on specific modules

Phase	Control Group	Intervention Group
Before Instruction	Student Survey 1 (Baseline) • Demographics • Knowledge quiz • Knowledge rating • Learning motivation scale • Self-efficacy scale	Student Survey 1 (Baseline) • Demographics • Knowledge quiz • Knowledge rating • Learning motivation scale • Self-efficacy scale
During Semester	Standard instruction with traditional simulation	Standard instruction plus JasperVR analytics software
After Instruction (Last Week of Semester)	Survey 2 (Post-test 1) • Knowledge quiz • Knowledge rating • Learning motivation scale • Clinical placement readiness scale • Self-efficacy scale • Feedback on traditional simulation experience • Clinical performance evaluation	Survey 2 (Post-test 1) • Knowledge quiz • Knowledge rating • Learning motivation scale • Self-efficacy scale • Clinical placement readiness scale • Feedback on JasperVR experience • System Usability Scale (SUS) • Clinical performance evaluation
Qualitative Feedback	—	Focus group discussion OR One-on-one phone interviews
After Clinical Placement	Survey 3 (Post-test 2) • Knowledge quiz • Knowledge rating • Learning motivation scale • Readiness for clinical practice scale • Self-efficacy scale • Reflections on placement	Survey 3 (Post-test 2) • Knowledge quiz • Knowledge rating • Learning motivation scale • Readiness for clinical practice scale • Self-efficacy scale • Reflections on placement
Cost Analysis	End of semester	End of semester

Surveys
The study employed a pre-post design within a mixed methods framework, collecting data through multiple surveys at different time points.
Pre-test (Survey 1): Administered in weeks 2–3 of the semester, prior to simulation activities.
Post-test 1 (Survey 2): Conducted during the final week of the semester.
Post-test 2 (Survey 3): Conducted following clinical placement.
Surveys were completed either online or on paper. Pre-test surveys assessed students' knowledge through multiple-choice questions, a self-reported knowledge scale (7-point Likert scale from 'not at all knowledgeable' to 'extremely knowledgeable'), motivation to learn (7-point Likert scale), and self-efficacy for learning. The self-

efficacy scale included 10–13 items where students rated confidence in performing clinical skills related to each module on a 5-point Likert scale ('not at all confident' to 'extremely confident'). Survey items were collaboratively developed with faculty and reviewed for content validity. Post-test surveys repeated these measures and additionally captured students' perceptions of the learning experience using a 5-point Likert scale based on McCausland *et al.* (2004). For VR participants, the post-test included the System Usability Scale (SUS), a 10-item tool providing a global measure of software usability.

Focus group interviews

Semi-structured interviews were conducted with students in the VR intervention group to explore their experiences with JasperVR, lessons learned, and suggestions for improvement.

Clinical assessment

Students provided consent to use de-identified results from Objective Structured Clinical Examinations (OSCEs) completed at the end of each semester. OSCEs evaluated actual clinical performance aligned with the content of each module, using simulated participants.

Economic evaluation

A cost-benefit analysis compared JasperVR with traditional simulation-based education (SBE). Costs per student were calculated for immersive, mannequin-based, and simulated patient scenarios, allowing a direct comparison of financial implications.

Data analysis

Quantitative Analysis: Data were processed using SPSS (Version 21.0). Descriptive statistics summarized demographic characteristics. Chi-squared tests assessed baseline equivalence between intervention and control groups. Differences in outcomes between groups and across time points (for 2019 cohorts) were evaluated using two-way repeated measures ANOVA.

Qualitative Analysis: Open-ended survey responses were transcribed verbatim and analyzed thematically. One researcher generated initial descriptive codes, which were reviewed and finalized in collaboration with a second researcher to produce a thematic framework. Data organization and analysis were supported by MS Excel.

Economic Analysis: Costs of developing and delivering JasperVR were compared to those of conventional SBE to determine financial efficiency and viability.

Results and Discussion

The study included 675 students across seven cohorts (Cohorts 1–7). Due to COVID-19 disruptions in 2020, all students received the VR intervention, as face-to-face simulations were canceled during Semester 1. Consequently, Survey 3 and post-placement OSCEs could not be administered for 2020 participants. The final sample consisted of 282 students in the traditional simulation control group and 393 students in the VR intervention group. **Table 2** presents participant characteristics, including cohort, program of study (Bachelor or Diploma of Nursing), age categories (18–25 and 26+ years), and gender distribution.

Table 2. Participant Demographics for the Full Sample Pearson Chi-Square tests revealed no significant differences between the Control (Simulation) and Intervention (VR) groups with respect to:
teaching cohort distribution ($\chi^2 = 10.4$, df = 6, $p = 0.108$)
program of enrollment ($\chi^2 = 3.22$, df = 1, $p = 0.073$)
enrollment status ($\chi^2 = 0.042$, df = 1, $p = 0.837$)
age group distribution ($\chi^2 = 0.043$, df = 1, $p = 0.836$)
gender ($\chi^2 = 2.91$, df = 1, $p = 0.088$)

Cohort	Control (Sim) *N*	Intervention (VR) *N*	Total *N*	%
Cohort 1	45	66	111	16.4
Cohort 2	29	31	60	8.9
Cohort 3	42	56	98	14.5
Cohort 4	23	54	77	11.4
Cohort 5	91	99	190	28.1
Cohort 6	34	63	97	14.4
Cohort 7	18	24	42	6.2
Total	282	393	675	100.0
Program	Control (Sim) *N*	Intervention (VR) *N*	Total *N*	%
BN	178	221	399	59.1
DN	104	172	276	40.9
Total	282	393	675	100.0

Age Group	Control (Sim) *N*	Intervention (VR) *N*	Total *N*	%
18–25 years	180	263	443	65.6
26–50+ years	90	127	217	32.1
Missing	12	3	15	2.2
Total	282	393	675	100.0
Gender	Control (Sim) *N*	Intervention (VR) *N*	Total *N*	%
Male	62	70	132	19.6
Female	203	320	523	77.5
Other	2	0	2	0.3
Missing	15	3	18	2.7
Total	282	393	675	100.0

Simulation participation

In the VR intervention group, nearly 95% of students actively engaged with the virtual scenarios. A small proportion (approximately 3–5%) were unable to participate due to device incompatibilities and were subsequently reassigned to the traditional simulation control group. In the control group, only around 15% of students were actively involved in the face-to-face simulations, while the remaining 85% assumed observer roles, which aligns with the standard practices at the institution.

Knowledge test outcomes

Baseline knowledge assessments indicated no systematic differences between the control and intervention groups prior to the intervention. Following the intervention (Survey 2), 15 of 17 independent t-tests revealed statistically significant improvements in the VR group ($p < 0.001$), demonstrating superior performance compared to the control group **(Table 3)**. However, by the time of Survey 3, after clinical placement, no significant differences were observed between the groups. This suggests that the initial knowledge gains achieved through VR were not maintained over time.

Table 3. Knowledge Test, Questions Q1 – Q10 responses pooled to give Total Score/10. Descriptive statistics (columns 4–7; N, Mean, StdDev and 95% Confidence Interval) for Control and Intervention Groups

Selection Property		Group	Descriptive Statistics				t-test for Equality of Means		
			N	Mean	Std. Dev.	95% C.I.	t	df	Sig.
All	All Cases	Control (Sim)	734	5.75	2.15	0.159	-1.4	1598.4	0.169
		Intervention (VR)	1115	5.89	2.21	0.132			
Module	Module 1	Control (Sim)	157	7.85	1.49	0.238	-1.8	279.8	0.080
		Intervention (VR)	267	8.10	1.23	0.150			
	Module 2	Control (Sim)	232	5.21	1.48	0.194	-0.9	527.7	0.361
		Intervention (VR)	327	5.33	1.65	0.182			
	Module 3	Control (Sim)	245	4.36	1.87	0.240	0.9	484.9	0.382
		Intervention (VR)	364	4.23	1.68	0.176			
	Module 4	Control (Sim)	100	7.09	1.62	0.324	-0.2	219.3	0.813
		Intervention (VR)	157	7.14	1.71	0.273			
Survey 2, Section B, Q1-10, total score/ 10 (cohorts 1–6)									
All	All Cases	Control (Sim)	511	6.09	2.24	0.20	-9.1	928.7	< 0.001**
		Intervention (VR)	810	7.16	1.84	0.13			
Module	Module 1	Control (Sim)	129	7.73	1.60	0.28	-4.3	194.8	< 0.001**
		Intervention (VR)	223	8.41	1.07	0.14			
	Module 2	Control (Sim)	129	5.68	1.78	0.31	-6.7	235.8	< 0.001**
		Intervention (VR)	217	6.93	1.51	0.21			
	Module 3	Control (Sim)	183	4.92	2.14	0.32	-3.9	346.2	< 0.001**
		Intervention (VR)	239	5.69	1.75	0.23			
	Module 4	Control (Sim)	70	6.84	2.21	0.53	-4.4	99.3	< 0.001**
		Intervention (VR)	131	8.13	1.40	0.24			
Survey 3, Section B, Q1-Q10 (cohorts 3, 4 and 6)									
All	All Cases	Control (Sim)	270	5.88	2.68	0.33	-0.6	570.9	0.541
		Intervention (VR)	442	6.00	2.69	0.26			
Module	Module 1	Control (Sim)	75	8.24	1.00	0.23	-1.3	155.7	0.188
		Intervention (VR)	120	8.43	0.99	0.18			
	Module 2	Control (Sim)	72	5.94	1.91	0.45	-1.1	136.0	0.257
		Intervention (VR)	121	6.26	1.71	0.31			
	Module 3	Control (Sim)	75	2.55	1.31	0.30	0.4	135.8	0.710
		Intervention (VR)	121	2.48	1.09	0.20			
	Module 4	Control (Sim)	48	7.29	1.61	0.46	-0.1	104.2	0.945
		Intervention (VR)	80	7.31	1.72	0.38			

Students' self-perceived knowledge and motivation

Immediately following the intervention, students in the VR group reported significantly higher ratings for self-assessed knowledge, motivation to learn, and readiness for clinical placement compared to the control group ($p < 0.01$, **Table 4**). However, these differences were no longer evident after completion of clinical placements, indicating that the initial improvements were not sustained over time.

Table 4. Students' self-perceived knowledge, motivation and preparedness for clinical placement or clinical practice. Descriptive statistics and Independent Samples t-test (All Cohorts. All Modules pooled. Surveys 2 and 3)

Survey 2 Question	Group	Descriptive Statistics				t-test for Equality of Means		
		N	Mean	Std. Dev.	95% C.I.	t	df	Sig.
KNOWLEDGE	Control (Sim)	493	4.57	1.495	0.134	-9.99	903.3	< 0.001**
	Intervention (VR)	786	5.37	1.240	0.088			
MOTIVATION	Control (Sim)	493	5.73	1.134	0.102	-6.04	968.0	< 0.001**
	Intervention (VR)	786	6.11	1.027	0.074			
PREPAREDNESS (for clinical placement)	Control (Sim)	493	5.03	1.163	0.104	-6.57	1018.1	< 0.001**
	Intervention (VR)	786	5.46	1.124	0.080			
Survey 3 Question	**Group**	**Descriptive Statistics**				**t-test for Equality of Means**		
		N	Mean	Std. Dev.	95% C.I.	t	df	Sig.
KNOWLEDGE	Control (Sim)	268	5.10	1.097	0.134	-0.45	515.35	0.653
	Intervention (VR)	439	5.14	0.978	0.094			
MOTIVATION	Control (Sim)	268	6.00	1.067	0.130	0.532	543.143	0.595
	Intervention (VR)	440	5.96	1.017	0.096			
PREPAREDNESS (for clinical practice)	Control (Sim)	245	5.28	1.161	0.148	0.48	464.156	0.632
	Intervention (VR)	401	5.23	1.017	0.102			

Self-Efficacy in learning

Following the intervention, students in the VR group reported significantly higher self-efficacy for learning in modules 3 and 4 compared with the control group ($p < 0.01$, **Table 5**). However, these differences were not sustained after the completion of clinical placements, suggesting that the initial gains in confidence diminished over time.

Table 5. Self-efficacy in learning, pooled responses to give Total Score/100, results resolved according to module number (1–4). Descriptive statistics (columns 4–7; N, Mean, StdDev and 95% Confidence Interval) for All Cohorts (i.e., both BN Cohorts and DN Cohorts), for Control and Intervention Groups. Independent Samples t-test comparing the mean values for the Control and Intervention groups. ** indicates significance at the $p < 0.01$ level

Selection Property		**Group**	**Descriptive Statistics**				**t-test for Equality of Means**		
			N	**Mean**	**Std. Dev.**	**95% C.I.**	**t**	**df**	**Sig.**
Survey 2	Module 1	Control (Sim)	121	81.00	10.05	1.83	-1.3	260.2	0.183
		Intervention (VR)	217	82.56	10.63	1.44			
	Module 2	Control (Sim)	130	78.78	10.57	1.85	-0.6	309.3	0.545
		Intervention (VR)	217	79.55	12.65	1.72			
	Module 3	Control (Sim)	182	70.04	14.96	2.22	-6.4	352.3	< 0.001**
		Intervention (VR)	238	78.91	12.63	1.64			
	Module 4	Control (Sim)	71	76.08	14.00	3.32	-4.1	117.1	< 0.001**
		Intervention (VR)	131	83.97	10.94	1.91			
Survey 3	Module 1	Control (Sim)	75	81.29	9.77	2.26	-0.2	166.3	0.821
		Intervention (VR)	120	81.63	10.55	1.93			

Module 2	Control (Sim)	72	76.00	12.27	2.89	0.3	160.6	0.787
	Intervention (VR)	121	75.48	13.48	2.45			
Module 3	Control (Sim)	73	72.05	14.89	3.49	-1.1	137.3	0.256
	Intervention (VR)	121	74.46	13.14	2.39			
Module 4	Control (Sim)	48	75.00	12.09	3.49	-1.1	100.3	0.289
	Intervention (VR)	78	77.37	12.20	2.76			

OSCE performance analysis

Objective Structured Clinical Examination (OSCE) data were collected for a total of 478 students, comprising 177 in the control group and 301 in the VR intervention group. Statistical comparison using Pearson's Chi-Square test ($\chi^2 = 0.267$, df = 2, $p = 0.875$) indicated no overall significant difference between the two groups.

When examining individual modules, mean OSCE scores for Modules 1 and 2 were comparable between the VR and control groups. In contrast, Module 3 showed a notable advantage for the VR group, with students achieving significantly higher scores ($p < 0.01$). Aggregating the results across all three modules revealed that the intervention group had higher mean OSCE scores overall, but this combined difference did not reach statistical significance ($p \geq 0.05$, **Table 6**).

Table 6. Mean OSCE Score (as %, StdDev and 95% Confidence Interval) for all cases (n = 478), for Control and Intervention Groups

Module Number	Group	Descriptive Statistics				t-test for Equality of Means		
		N	Mean Score %	Std. Dev.	95% C.I.	t	df	Sig.
Module 1	Control (Sim)	30	79.8	16.6	6.06	0.726	43.3	0.472
	Intervention (VR)	51	77.3	10.7	2.98			
Module 2	Control (Sim)	99	70.0	11.1	2.23	− 0.790	241.9	0.431
	Intervention (VR)	162	71.3	14.0	2.19			
Module 3	Control (Sim)	48	49.1	17.7	5.10	-3.606	94.3	0.000**
	Intervention (VR)	88	60.4	17.2	3.66			
Pooled Modules	Control (Sim)	177	66.0	17.8	2.67	-1.931	332.3	0.054
	Intervention (VR)	301	69.1	15.7	1.80			

Views about the module (survey 2)

All t-test comparisons of the mean ratings between the control and VR intervention groups for module-related perceptions were statistically significant, with most showing p-values below 0.01 and three reaching $p < 0.001$ **(Table 7)**.

Table 7. Views about the module, responses pooled to give Total Score/50, (cohorts 1–6 -no data cohort 7)

Selection Property	**Group**		**Descriptive Statistics**				**t-test for Equality of Means**		
			N	**Mean**	**Std. Dev.**	**95% C.I.**	**t**	**df**	**Sig.**
All	All Cases	Control (Sim)	382	40.37	6.59	0.67	-8.9	665.4	< 0.001**
		Intervention (VR)	791	43.88	5.71	0.41			
Module	Module 1	Control (Sim)	77	41.34	6.41	1.46	-2.8	125.6	0.005**
		Intervention (VR)	218	43.72	5.98	0.81			
	Module 2	Control (Sim)	125	41.32	5.22	0.93	-3.9	272.0	< 0.001**
		Intervention (VR)	205	43.67	5.48	0.77			
	Module 3	Control (Sim)	127	39.65	6.89	1.22	-5.1	222.8	< 0.001**
		Intervention (VR)	237	43.35	5.80	0.75			
	Module 4	Control (Sim)	53	38.42	8.32	2.28	-5.7	69.1	< 0.001**
		Intervention (VR)	131	45.44	5.21	0.91			

Qualitative findings

Analysis of intervention students' feedback across the four JasperVR modules revealed several recurring themes **(Table 8)**. Participants frequently commented on the realism of the VR scenarios and appreciated the opportunity to repeatedly practice each scenario, which reinforced their learning. They emphasized the value of making mistakes in a safe environment without affecting actual patient care. Many students noted that the VR experience was less stressful and intimidating compared to traditional simulation exercises. The scenarios were also recognized for promoting critical thinking and supporting the acquisition of knowledge and skills necessary to handle similar clinical situations.

Despite generally positive feedback, some concerns were raised. A few students found the VR headsets uncomfortable for extended use. While most perceived the VR environment as less daunting than conventional simulation, some expressed a preference for more hands-on involvement rather than interacting via option selection. Additionally, a small number suggested that their clinical reasoning could be further enhanced if scenarios allowed for multiple correct responses, offered alternative approaches to managing cases, or included multiple variations per module. Appendix 1 provides a detailed overview of students' reported highlights and challenges for each module.

Table 8. Qualitative data for intervention students' views on Jasper VR

Section	Theme	Representative Quotes
Most Enjoyed Aspects		
Common across all modules	Realism	"It felt authentic—like a genuine clinical encounter—and prepared me for real-world challenges." "The realism of the scenario allowed reflection on my decision-making process." "Varied settings and locations enhanced the immersive, lifelike quality of the VR experience."
	Safe rehearsal & learning from errors	"I appreciated the structured information flow and the ability to select incorrect responses to see patient outcomes." "Feedback highlighted both correct and incorrect actions, showing consequences of poor choices—highly educational." "'Mastery mode' demonstrated expert-level responses." "Even wrong paths were fully acted out with high production quality."
	Lower anxiety & greater confidence vs. traditional simulation	"Not being physically present reduced intimidation." "VR was far superior to in-person sim; it was welcoming, anxiety-free, and facilitated deep learning." "JasperVR activities built my confidence, enabling calm performance."
	Unlimited practice opportunities	"I could repeat modules without pressure—stress-free learning."
	Enhanced critical thinking	"Full immersion and a clear patient handover guided my clinical management." "Multiple decision points fostered advanced reasoning and problem-solving within the scenario."
Least Enjoyed Aspects		
Common across all modules	Technical issues: VR headset	"Headsets malfunctioned frequently; mobile viewing was more reliable." "The VR-GX was cumbersome; phone mode was preferable, especially while wearing glasses."
	Scenario: Limited interactivity	"I couldn't physically engage with the patient or environment." "I was a passive observer rather than an active participant." "I wanted greater hands-on involvement." "Break content into shorter, more interactive segments for better retention."
	Scenario: Clinical reasoning depth	"More decision points and alternative pathways would improve realism." "Include options that are plausible but not ideal—avoid a single 'correct' path."
	Scenario: Knowledge reinforcement	"Include post-scenario quizzes to consolidate key learning points."
	Need for diverse & advanced scenarios	"Add hospital-based triggers (e.g., delayed surgery) leading to escalation." "Show varied expressions of aggression; include bedside confrontations." "Expand content on deteriorating patients with greater clinical depth in VR."

System usability scale

The mean scores of the pooled usability scale are very complimentary of the usability of the system, particularly its 'ease of use' (Q3) and its property of being 'easy to learn quickly' (Q7) **(Table 9)**.

Table 9. System Usability Scale responses. Descriptive statistics (N, mean value, standard deviation and 95% confidence interval) for the pooled cohort (N = 306, Cohorts 1,2,3,4,5 and 6 combined) responses

Question #	Question Text	Cohort	N	Mean	Std. Dev.	95% C.I.
Q1	I think that I would like to use this system frequently	All	305	4.06	0.97	0.11
Q2	I found the system unnecessarily complex	All	306	2.11	1.19	0.14
Q3	I thought the system was easy to use	All	306	4.22	0.92	0.10

Q4	I think that I would need the support of a technical person to be able to use this system	All	306	2.12	1.25	0.14
Q5	I found the various functions in this system were well integrated	All	305	3.95	0.93	0.11
Q6	I thought there was too much inconsistency in this system	All	306	2.02	1.06	0.12
Q7	I would imagine that most people would learn to use this system very quickly	All	305	4.19	0.87	0.10
Q8	I found the system very cumbersome to use	All	300	2.53	1.25	0.14
Q9	I felt very confident using the system	All	306	4.29	0.82	0.09
Q10	I needed to learn a lot of things before I could get going with this system	All	306	2.27	1.28	0.15

Student feedback from qualitative surveys

The qualitative survey data reinforced the quantitative results. Students in the intervention group highlighted the flexibility of revisiting the VR scenarios at their own pace as a major advantage:

"Participating in JasperVR was a really engaging way to learn, and I liked that I could replay the scenarios as many times as I wanted."

"Given the current circumstances, VR simulations were an excellent alternative, and being able to repeat them whenever needed made learning much more accessible."

Many students also reported that VR simulations felt less intimidating compared to traditional face-to-face simulations and appreciated the chance to make decisions and observe the consequences in a safe environment:

"I found VR less stressful than doing simulations in front of my entire class and actors. It was helpful to see what would happen if I made a wrong choice, and being able to repeat the simulations was really valuable."

Some students did note minor challenges, particularly with headset comfort and navigation controls:

"I liked that I could revisit the simulations whenever I wanted, though I sometimes struggled with controlling it using the VR headset."

Cost-effectiveness and feasibility of JasperVR

The economic analysis revealed that implementing JasperVR is substantially less expensive than traditional simulation-based education (SBE). **Table 10** shows that delivering a single JasperVR module annually costs approximately $3,350, while the cost of running one SBE scenario per year for both Bachelor and Diploma nursing programs is about $18,670. This suggests that VR simulations may offer a cost-effective and scalable alternative to traditional simulation approaches.

Table 10. The cost of delivering the VR and SBE for the Bachelor and Diploma of Nursing groups

Category	Item	JasperVR (costs per individual scenario)		Bachelor of Nursing		Diploma of Nursing	
		Hrs	Cost	Hrs	Cost	Hrs	Cost
One-off work							
	Script development and review	160	$8,000	20	$1,000	20	$1,000
	Rehearsals	40	$2,000	—	—	—	—
	Filming (1 day) crew	—	$3,000	—	—	—	—
	Filming (1 day) actors	64	$2,560	—	—	—	—
	Filming (1 day) teachers	10	$500	—	—	—	—
	Document update	10	$500	—	—	—	—
	Software development	160	$8,000	—	—	—	—
	Testing and QA	160	$8,000	—	—	—	—
	Project development overhead	60	$3,000	—	—	—	—
Totals		664	$35,560	32	$1,600	28	$1,400
On-going use							
	Software license	—	$2,000	—	—	—	—
	Admin preparation	15	$750	—	—	—	—
	Pre-brief students	4	$200	—	—	—	—
	Debrief students	4	$200	—	—	—	—
	Technical support	4	$200	—	—	—	—
	Preparations	—	—	23	$1,150	16	$800
	Sim day – teachers	—	—	48	$2,400	32	$1,600

	Sim day – actors	—	—	21	$840	32	$1,280
	Sim day – others (sim techs)	—	—	10	$500	10	$500
	Additional remedial sim day (depending on group size)	—	—	102	$5,100	190	$4,500
Totals		—	$3,350	204	$9,990	180	$8,680

This study demonstrated that Virtual Reality Simulation (VRS) offers nursing students engaging, authentic, and immersive learning experiences. Participants reported that the VR scenarios felt realistic and helped strengthen their clinical reasoning skills, which is crucial for preparing students for actual clinical practice [19]. Our findings also support the use of VRS for teaching specific behavioral competencies, including teamwork and clinical decision-making [19, 20]. Compared to traditional simulation-based education (SBE), VRS accommodated a larger number of students, all of whom could actively participate in decision-making processes. JasperVR emerged as a sustainable and cost-efficient alternative to conventional SBE methods.

Overall, VRS was effective in enhancing student knowledge and performance, corroborating previous research on VR in nursing education [8, 14-16, 21]. The immersive nature of VR can increase cognitive load because learners must process a wealth of sensory information, coordinate multiple senses simultaneously (e.g., vision and hearing), manage controllers, and navigate a three-dimensional environment. Despite this, our results indicate that immersive VRS effectively supports cognitive learning and serves as a powerful teaching tool [9, 20].

Analysis of OSCE outcomes revealed that VRS students achieved significantly higher scores for Module 3 (managing patients with cognitive impairment) immediately post-intervention compared to the traditional simulation group. Students highlighted the benefits of practicing communication, collaboration, handover documentation, and patient assessment within the VR environment. While these gains were not maintained post clinical placement, the findings suggest that repeated engagement with VR scenarios could reinforce these competencies. The immediate post-intervention knowledge gains observed in VRS students were also not sustained over time, emphasizing the importance of revisiting VR content to consolidate learning and attain proficiency [22].

Students valued the opportunity to practice clinical skills in realistic, safe settings while exploring new perspectives. VR simulations offer heightened realism and immersion, allowing learners to experience scenarios that closely mimic real-life clinical situations. The interactive and motivating nature of VRS has been associated with improved learning outcomes, including enhanced engagement and skill acquisition [19, 23, 24]. Mastery mode within JasperVR allowed students to observe expert demonstrations and practice strategies such as de-escalation techniques, reinforcing skill development through repetition. Compared to SBE, which may limit opportunities for repeated practice, VRS enables students to refine their abilities efficiently and safely, especially in scenarios involving aggressive patients or high-risk situations [25].

Although some students noted a lack of hands-on practice within VR scenarios, many appreciated the immersive environment for activities such as assessing deteriorating patients and performing handovers. Previous studies have similarly shown that simulation of acute patient deterioration is effective for preparing nursing students for clinical practice [26]. VR learners valued the ability to repeatedly experience scenarios, observe the outcomes of their choices, and learn from mistakes without real-world consequences, which enhanced self-awareness and decision-making skills [19, 25]. Participants also reported reduced anxiety and increased psychological safety in VR compared to traditional simulations [24, 27, 28], reinforcing findings from prior research that VR can provide a less stressful learning environment.

While the VR scenarios offered students immediate feedback and the ability to correct mistakes in real time, some participants noted that each scenario presented only one correct option. They suggested that allowing a broader range of patient management choices would better reflect real-world clinical situations. Similarly, another study involving a VR scenario where patients unnecessarily requested antibiotics from a general practitioner reported participant skepticism regarding VR's ability to capture the diversity and complexity of patient responses [28]. Learning systems for healthcare professionals that rely on menu-based actions may limit the development of critical clinical reasoning skills [29]. VR simulations, however, can be tailored to the needs of learners and specific learning objectives, which should be considered in future scenario development.

Overall, participants in this study responded positively to the usability of VR technology, consistent with findings from other immersive VR nursing studies [11, 30]. Usability—including ease of use and user satisfaction—is a critical factor in VR-based learning [7]. When considering the economic feasibility of VR simulations (VRS), cost-effectiveness compared to standard simulation-based education (SBE) depends on factors such as initial investment, maintenance, scalability, and accessibility. One prior study reported a lower cost-utility ratio for virtual simulation (US$1.08) compared to mannequin-based simulation (US$3.62) [31]. In our study, VR required substantial upfront costs for software, hardware, and development, making it initially more expensive than SBE. This aligns with Liaw *et al.* who highlighted the importance of funding for developing virtual worlds in nursing education due to high design and development costs [32]. VR simulations also require ongoing software updates and maintenance, whereas SBE may require periodic replacement of equipment. Nonetheless, our economic evaluation indicated that long-term delivery costs for VR are reduced due to less on-campus teaching and increased opportunities for independent learning. As Pottle noted, simulation costs are often difficult to define, vary between institutions, and are frequently under-reported [33]. Further research is needed to fully assess the cost-effectiveness of VR versus SBE for nursing students [22].

Our study also found that learners initially needed more time to become comfortable with VR technology and set up equipment compared to SBE. However, VR simulations are more scalable, supporting larger groups of students simultaneously and facilitating future research. Remote access provides flexibility and convenience, particularly for students without easy access to physical simulation labs, saving time and eliminating travel. During the COVID-19 pandemic in 2020, all JasperVR learning shifted to remote delivery, further reducing time required for briefing and debriefing.

Limitations

This study focused solely on undergraduate students, so further research is needed to explore VR applications across the broader healthcare professional spectrum. Some students suggested that clinical judgment could improve if scenarios offered multiple correct approaches. Future studies could involve students in scenario development to incorporate their perspectives. Repeated exposure to similar situations may help students gain confidence in responding appropriately in real-life settings. Future research could also examine students' concerns regarding limited hands-on experience, reduced patient interaction, and how these factors translate to clinical practice.

Due to the COVID-19 pandemic, control and crossover groups could not be implemented in 2020, and all students participated in the JasperVR intervention. Additionally, Survey 3 and clinical assessments were canceled due to widespread clinical placement and assessment disruptions, resulting in a larger intervention group compared to control.

Conclusion

Through collaborative content and software development, a sophisticated, scalable, highly usable, and authentic learning experience was created for pre-licensure nursing students. JasperVR enabled more students to engage actively in immersive simulation at their own pace and location. The platform promoted critical thinking and decision-making, offering an efficient, cost-effective, and sustainable learning tool. VR simulations provided immersive, repeatable, and feedback-rich experiences, establishing JasperVR as a valuable educational resource for future nursing students.

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