Virtual Reality Simulation for Undergraduate Nursing Students for Care of Patients with Infectious Diseases: A Mixed-Methods Study

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Table of Contents

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Abstract

Background: Virtual reality simulation (VRS) teaching provides nursing students with a safe and immersive learning environment and immediate feedback, thereby enhancing learning outcomes. Before the COVID-19 pandemic, nursing students rarely had training and opportunities to care for patients with infectious diseases in isolation units. However, as evidenced by the pandemic, care for patients with infectious diseases remains a global priority.

Objective: To examine the effectiveness of VRS for caring for patients with infectious diseases on nursing students' theoretical knowledge, learning motivation, and attitudes, as well as to evaluate their experiences of VRS.

Methods: For this two-phase mixed-methods study, third-year undergraduate nursing students enrolled in the Integrated Emergency and Critical Care course from a university in Taiwan were recruited. Phase one used a quasi-experimental design to compare the learning outcomes of students undergoing VRS group with those undergoing traditional teaching (the control group). Tools include an infection control written test, an Instructional Materials Motivation Survey (IMMS) and a learning attitude questionnaire. The experimental group used the VRS lesson named "Caring for a Patient with COVID-19 in the Negative Pressure Unit" in the infection control unit. In phase two, semi-structured interviews were conducted to elucidate the students' learning experience.

Results: Compared with the control group, the VRS group had significantly higher scores in the infection control written test (t = 2.704, P =.008) and significantly higher learning motivation (t = 2.094, P =.039). A statistically significant regression coefficient for learning attitudes before the end of the semester compared with the pre-test for two groups (? = 0.230, P =.009). The students' learning experiences of VRS group were categorized into four themes: applied professional knowledge to patient care, enhanced infection control skills, demonstrated patient care confidence and participated in real clinical cases. The core theme is strengthening clinical patient care competencies.

Conclusions: The findings revealed that the VRS teaching was effective in enhancing undergraduate nursing students' infection control knowledge, learning motivation and attitudes. Qualitative insights supported the quantitative findings, suggesting a holistic outcome of VRS teaching in nursing education, including enhanced learning outcomes. The positive impact on student motivation and attitudes indicates a potentially transformative shift in how nursing education can be delivered, especially in a post-COVID-19 era where digital and remote learning tools are becoming increasingly important. Clinical Trial: N/A

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Introduction

Virtual reality (VR) has emerged as an innovative teaching strategy in nursing education. VR technology uses simulated scenarios to overcome time and space limitations, providing students with opportunities to learn in safe and realistic settings and receive immediate feedback.[1] VR simulation (VRS) teaching strategies enhance learning motivation, student immersion, knowledge and skill acquisition, confidence,[2,3-] motivation, active participation, and learning effectiveness.[4-6] The goal of undergraduate nursing education is to prepare students for clinical practice, making it crucial to strengthen students' professional competencies and attitudes. Integrating information technology into nursing education helps the students achieve better learning outcomes. Nursing education should align with the broader environment of clinical practice, incorporating technology to meet effectively assist students in developing their competencies.[7]

Background

The COVID-19 pandemic has significantly impacted nursing curricula and teaching worldwide. In emergency and critical care, university-level nursing curricula must mirror clinical environments. Emphasizing situated learning enhances students' abilities and confidence in providing emergency patient care.[8-9] Before the pandemic, nursing students rarely had opportunities to care for patients with infectious diseases in isolation units. However, the demand for care related to infectious diseases remains a global priority.[9] Strengthening courses on infectious diseases can help students develop positive attitudes toward clinical practice.[10] Infectious diseases courses can be updated with more practical experience to help nursing students develop positive attitudes when dealing with patients with infectious disease in their clinical practice.

Learning theories related to VR teaching include constructivism, situated learning, and experiential learning. During VR learning, learners actively absorb new information and construct new knowledge.[11] Situated learning theory emphasizes real-world interactions and activities in

authentic contexts, which help transform these experiences into applicable knowledge.[15] VR provides an interactive virtual environment by using visual effects to present abstract problems, thus offering opportunities for active manipulation and repeated practice.[11] Experiential learning theory posits that learning is the transformation of experience, where knowledge creation results from interactions, conflicts, and problem-solving between individuals and their environment. This theory suggests that immersive technology can provide meaningful experiences.[12] Compared with other teaching methods, VR teaching has been demonstrated to be easy to use and beneficial, demonstrating positive and active learning experiences[13] and enhanced learning outcomes, including improvements in knowledge, skills, and clinical decision-making.[14-15] High engagement in VR environments offers student's experiences closely aligned with clinical practice, thereby boosting learning motivation and attitudes, leading to better educational outcomes.[14-15]

Motivation and attitude significantly influence learning outcomes. Enhanced motivation strengthens active learning and improves results.[12,16] Motivation has been positively correlated with learning outcomes, making learning easier and fostering proactive engagement.[17,18] Keller's ARCS model of motivation focuses on attention, relevance, confidence, and satisfaction and includes a learning motivation scale to assess motivational aspects within a course.[12,16] Designing courses with integrated motivational models can inspire learners, enhance motivation, and increase classroom engagement.[19-20] Using VR in healthcare education, particularly emergency and critical care courses, can address the limitations of clinical settings and traditional teaching methods, especially due to resource constraints[21-24] and stimulate learners' motivation, promote active participation, and enhance learning outcomes.[25-26] Incorporating VR teaching can align courses more closely with clinical practice, providing a solid foundation for students' professional knowledge and skills.

Objectives

This study examined the effectiveness of VRS teaching for the care of patients with infectious diseases on nursing students' learning motivation, attitudes, and outcomes, as well as explored their

learning experiences associated with engaging a VRS program.

Methods

This study adopted a mixed-methods approach to provide a comprehensive evaluation of the VRS teaching for caring for patients with infectious diseases in the infection control unit of the Integrated Emergency and Critical Care course. The first phase used a quantitative study design to investigate the learning effectiveness of this method, whereas the second phase used qualitative phenomenography to understand students' experiences and perceptions of the program.

Phase One

A quasi-experimental design was employed to compare the learning outcomes of knowledge, motivation, and attitude between the students in the VRS teaching (the experimental group) and those in traditional teaching courses (the control group). Data were collected from August 2022 to July 2023.

Participants

This study used convenience sampling and was conducted at a clinical competence center at a university in Taiwan. Third-year undergraduate nursing students enrolled in the Integrated Emergency and Critical Care course were potential participants. One class of students was included as the experimental group, and other as the control group. The selection criteria for the experimental group included (a) ≥20 years old, (b) being enrolled in the Integrated Emergency and Critical Care course, and (c) being willing to participate in this study. Students absent from the infection control unit were excluded. For sample size estimation, an effect size of 0.25, correlation of 0.5, power of 0.8, and α value of 0.05 were considered, resulting in a sample size of ≥86, with ≥43 participants per group.

Instruments

Infection Control Written Test

The infection control knowledge assessment involved a written test for students before (T0) and after the infection control lesson (T1). The test comprised 10 multiple-choice questions designed to assess the students' knowledge before learning, aiming to gauge their initial capabilities and prior knowledge. To minimize the impact of psychological memory recall on the students' performance in the post-test, adjustments were made to the order of questions and modifications to some question stems. The written questions were reviewed by instructors and clinical experts for expert content validity index.

Instructional Materials Motivation Survey

The Instructional Materials Motivation Survey (IMMS) was administered before (T0) and after the infection control lesson (T1) and during the last week of the semester (T2). Designed primarily to assess students' motivation in learning a course,[12] the IMMS consists of 36 items across four subscales according to the ARCS motivation model (Attention, 12 items; Relevance, 9 items; Confidence, 9 items; and Satisfaction, 6 items), which are rates on a five-point Likert scale, with higher scores indicate greater learning motivation. The original IMMS scale demonstrated high reliability with Cronbach's alpha values ranging between 0.81 and 0.96.[26] In this study, the Cronbach's alpha of IMMS was 0.94, indicating good reliability.

Learning Attitude Questionnaire

A learning attitude questionnaire was administered at T0, T1, and T2. This 20-item self-reported questionnaire was designed by the research team and evaluates the students' attitudes toward caring for patients with infectious diseases and students' attitudes toward participating in the infection control unit. The items are rated on a five-point Likert scale, where 1 indicates "strongly disagree", 2 "disagree", 3 "neutral", 4 "agree", and 5 "strongly agree". A higher score indicates a more positive learning attitude. The average content validity index (CVI) was 0.9, and Cronbach's alpha was 0.955, indicating good reliability.

Intervention

VRS Lesson Plan: Caring for a Patient with COVID-19 in the Negative Pressure Unit

In the infection control unit, VRS teaching was designed for the experimental group. The scenario involved a patient with a fever visiting the emergency department for triage, who was confirmed as having COVID-19 and then admitted to a negative pressure isolation unit (Figure 1). The teaching content focused on a nurse providing care through a negative pressure isolation room, including correctly donning and doffing the personal protective equipment (PPE). The learning objectives of this lesson were set for students to distinguish care for patients with infectious diseases, don and doff PPE, and provide care for the patients. The lesson leveraged VR technology to provide visual effects and interactive scenarios to enhance students' awareness and provide opportunities for practical exercises, thereby increasing learning outcomes.[27] The assessment included the standard procedure for applying PPE, including N95 masks, goggles, hair caps, and gloves. After the students completed the assessment, the computer screen directly pointed out missed items to them; this immediate feedback was used to enhance learning effectiveness.[1]

Figure 1 Screen captures of VRS videos

Procedure

The infection control unit spanned 2 weeks, with a 100-minute lesson per week. Before course commencement, the VRS group students received lecture notes, prerecorded online VR videos on

donning and doffing PPE into a negative pressure isolation unit, and teaching on VR system operation. The first week of class involved a 100-minute lesson on infection control theory and skills. The second week involved a 100-min VRS teaching. The entire class was divided into five groups, with 8–10 students per group working together on the drills. The lesson included an introduction to the VR system operation (5–10 min), group VRS scenario drills (30–40 min), and then each student executing their part of the VRS lesson (approximately 6–8 min). Upon completion, the system provided feedback, serving as the students' learning outcomes. The group members first discussed the session among themselves, followed by a 10-min instructor-led debriefing session, wherein the students were encouraged to ask questions and share their thoughts on the VRS execution. Feedback and reflection were included to enable the students to consolidate their learning content and transform it into learning outcomes. Next, the groups switched roles and conducted the second round of drills and discussions for another 30–40 min. A pre-test and post-test on infection scenario cases were administered to understand the students' learning outcomes, motivation, attitudes and knowledge toward the infection control unit. The control group followed the traditional infection control unit course, which includes theoretical lectures in the first week and practicing donning and doffing PPE isolation gowns in the second week.

Data Analysis

The data collected for this study were individually coded and entered into a computer for analysis using SPSS version 22.0 (IBM Crop., Armonk, NY). The participants' characteristics were analyzed using frequency, percentage, mean, and standard deviation for categorical and continuous variables. A paired t test was employed for between-group comparisons in the pre-test and post-test measurements. Generalized estimating equations (GEE) were used to estimate the marginal means of the results from the learning motivation and attitude scales measured at the three time points, with standard errors included in the result. The results were considered significant at $P < .05$.

Phase Two

The qualitative study used phenomenography to understand students' experiences and perceptions of engaging in VRS teaching.

Phenomenography

Phenomenography represents "phenomenon" and "experience," emphasizing the commonality and generality of learners' thoughts or concepts regarding their experience of a specific phenomenon and focusing on the description of people's understanding of this experience.[28] Phenomenography aims to understand how learners organize and structure the content learned during the learning process.[28] This study compared students' interview contents to identify how past learning experiences affect learning outcomes, serving as a basis for improving continuous education programs. This study used phenomenography to determine the students' learning outcomes and experiences with the VRS teaching in caring for patients with infectious diseases.

Participants

Experimental group students who met the following inclusion criteria were recruited: (A) being ≥20 years old, (B) being enrolled in the integrated acute and critical care course and participating in VRS teaching, and (C) consenting to and accepting the recording of interviews. Students absent from the infection control unit were excluded.

Procedure

The participants underwent in-depth semi-structured interviews. In-depth interviews facilitate meaningful conversations, providing comprehensive outcomes and detailed understanding of complex issues.[29] The interview questions in a phenomenographic study need to be as open-ended as possible to remain true to the participant's thoughts. The interview guide is presented in Appendix A. In-depth interviews in this study help build knowledge and experiences of nursing students' engagement with VRS teaching. Each eligible participant received a consent form, detailing the study purpose, voluntary participation, and confidentiality of the research content. The participants filled the consent forms and arranged for interview times. Interviews were audio-recorded and

ranged from 42 to 62 minutes. The sample size of 18 students was sufficient to generate rich data and reach saturation.

Data Analysis and Trustworthiness

After the interviews, the researcher transcribed the audio recordings verbatim to ensure detailed documentation. The data analysis was based on the seven steps of phenomenographic analysis: familiarization, segmentation, summarization, categorization, comparison, naming, and contrasting.[29] The trustworthiness of the research findings was established using Lincoln and Guba's[30] criteria of credibility, transferability, dependability, and confirmability. Regarding credibility, phenomenographic research emphasizes the accurate description of each part of the study process, how the researcher's ideas are applied to phenomena, the precise formulation of interview questions and processes, and the detailed analysis and presentation of conclusions. Peer debriefing, involving collaborative data analysis to explore different meanings, enhances data interpretation and credibility, aiding in the formation of credible research outcomes. Transferability supported by providing in-depth data that represent the full picture of the research, showing its relevance and context. Dependability is achieved by supporting categorizations with excerpted interview content, demonstrating the similarities and differences among participants in relation to the phenomenon, and confirming the logical relationship between the collected data and phenomena captured by the descriptive categorization. Confirmability is established by noting the interviewer's feelings and thoughts related to the interview process, thereby creating an audit trail. The research data analysis is faithfully described, with detailed records of decisions made and strategies adopted during concept formation, reflecting on theoretical and methodological aspects to establish an audit trail and the confirmability of the result.[31]

Ethical Consideration

Ethical approval was obtained from the Institutional Review Board (number: 202002386B0). The study emphasized voluntary participation, confidentiality, anonymity, the right to withdraw, and

the assurance that the students' academic results would not be affected by the decision to participate or not. All participants provided written informed consent.

Results

Participant Demographic Characteristics in Phase One

Phase one consists of 107 third-year undergraduate students, including 47 in the experimental group with the VRS teaching and 60 in the control group with practical sessions on donning and doffing isolation gowns. The participants were predominantly female at 92.5% (N = 99), with an average age of 21.14 (SD=0.69) years.

Table 1 Participant's demographic characteristics (N=107)

Participant Demographics	Study Groups		Total Participants (N=107)
	VRS (N=47) N (%) or Mean ± SD	Control (N=60) N (%) or Mean ± SD	N (%) or Mean ± SD
Gender			
Male	2(4.3)	6(10)	8(7.5)
Female	45(95.7)	54(90)	99(92.5)
Age			21.14 ± .69
Male	22.00 ±1.41	20.50 ± .55	20.88 ± .99
Female	21.40 ± .54	20.96 ± .70	21.16 ± .67

Effectiveness of VRS in Infection Control Theoretical Knowledge

Pre-test and post-test assessments of knowledge in infection control were conducted in T0 and T1, with a total score of 10 points. The results revealed that all students had an average pre-test knowledge score of 7.58 (SD=1.13) and post-test knowledge score of 8.58 (SD=1.16), indicating improved knowledge after course completion (t = −7.08, *P* <.001). The VRS group had significantly higher post-test scores than the control group (t = 2.704, *P* =.008), suggesting that VRS teaching is more effective in improving students' knowledge (Table 2 and Figure 2).

Table 2 Comparison of theoretical knowledge in two groups (N=107)

Variable	T0 M (SD)	T1 M(SD)	t Value	*P* Value
Knowledge assessment				
VRS	7.77 (1.05)	8.89 (0.79)	-7.47	<.001***
Control	7.43 (1.18)	8.33 (1.34)	-4.04	<.001***
t Value	1.516	2.704		
P Value	.132	.008**		

Total	7.58 (1.13)	8.58(1.16)	-7.08	<.001***

T0: Pre-test; T1: Post-test; ** *P* <.01; *** *P* <.001

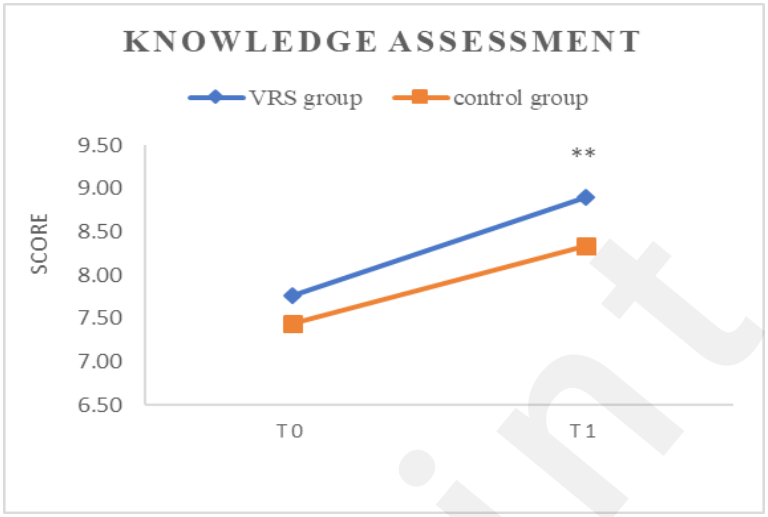

Figure 2 The trend of change in infection control knowledge in two groups

Effectiveness of VRS on Student Learning Motivation

The learning motivation of all students gradually increased from T0 (3.84 ± .47), T1 (3.94 ± .40), to T2 (4.01 ± .49). Compared with the control group, a significantly higher motivation was showed in the VRS group than the control group at T2 (t = 2.094, *P* =.039). On the basis of the ARCS model, the VRS group in the attention dimension showed statistically significant improvements than control group in T1 and T2 (*P* =.023 and .037, respectively). Confidence in the VRS group was significantly lower than that of the control group at T0 (t = −2.115, *P* =.038) but higher than the control group at T2 (t = 2.868, *P* =.005; Table 3).

Table 3 Comparison of learning outcomes between two groups at different time points (N=107)

Variable		T0			T1			T2		
		Mean (SD)	t Value	*P* Value	Mean (SD)	t Value	*P* Value	Mean (SD)	t Value	*P* Value
Motivation	VRS	3.84(.57)	.088	.930	4.01(.46)	1.432	.156	4.11(0.49)	2.094	.039*
	Control	3.83(.38)			3.89(.34)			3.92(0.46)		
Attention	VRS	3.84(.67)	.910	.365	4.03(.52)	2.302	.023*	4.12(0.54)	2.108	.037*
	Control	3.74(.48)			3.82(.42)			3.88(0.59)		
Relevance	VRS	4.15(.54)	.761	.449	4.21(.48)	.882	.380	4.32(0.49)	.844	.400
	Control	4.07(.41)			4.14(.37)			4.25(0.46)		
Confidence	VRS	3.45(.58)	-2.115	.038*	3.65(.49)	.861	.391	3.76(0.59)	2.868	.005**
	Control	3.66(.40)			3.58(.43)			3.46(0.48)		
Satisfactory	VRS	3.98(.64)	.513	.609	4.18(.51)	.476	.635	4.32(0.56)	1.251	.214
	Control	3.92(.44)			4.13(.50)			4.18(0.58)		
Attitude	VRS	4.09(.57)	-.596	.553	4.34(.52)	.028	.978	4.41(0.55)	.284	.777
	Control	4.15(.50)			4.34(.56)			4.38(0.47)		

T0: Pre-test; T1: Post-test; T2: the end of the semester

* *P* <.05 ** *P* <.01

In order to avoid bias resulting from the differences in ARCS model observed between the two groups at baseline, the GEE model was used to analyze and compare the individual variables of the groups (SBVR group and control group) between the study end-point (T3), the after the infection lesson (T2) and baseline (T0). The GEE results revealed a significant increase in the Relevance for all participants at T2 compared with T0, with a regression coefficient of β = 0.172 (*P* = 0.028). A significant difference was noted in the Confidence component T2 and T0 (β = −0.193, *P* = 0.016), but the parameter estimate is negative, showing that the total study cohort. For Satisfaction, significant differences were both T1 compared with T0 (β = 0.211, *P* =.013) and T2 compared with T0 (β = 0.264, *P* =.005). To understand intervention effectiveness, an analysis of the interaction effects between the two groups at different time points indicated that the Confidence in the experimental group from (T2–T0) and (T1–T0) had significant regression coefficients (β = 0.507, *P* <.001; β = 0.288, *P* =031), with positive parameter estimates (Table 4).

Table 4 Analysis of the VRS on Student Learning Outcomes (N=107)

	Variable	Beta Coefficient (B)	standard error (SE)	95% Wald Confidence Interval			*P* Value
Motivation	Intercept	3.832	.049	3.737	to	3.927	.000***
	Study group (VRS vs. control)	.008	.095	-.178	to	.195	.929
	Time point						
	T2 vs. T0	.088	.077	-.062	to	.238	.251
	T1 vs. T0	.061	.065	-.066	to	.188	.346
	Study group × time point						
	VRS ×[T2 – T0]	.186	.133	-.074	to	.447	.161
	VRS ×[T1 – T0]	.107	.124	-.136	to	.350	.389
Attention	Intercept	3.738	.061	3.617	to	3.858	.000***
	Study group (VRS vs. control)	.101	.115	-.123	to	.325	.377
	Time point						
	T2 vs. T0	.147	.097	-.044	to	.338	.130
	T1 vs. T0	.086	.082	-.074	to	.246	.291
	Study group × time point						
	VRS ×[T2 – T0]	.133	.158	-.177	to	.443	.400
	VRS ×[T1 – T0]	.109	.147	-.180	to	.398	.460
Relevance	Intercept	4.074	.052	3.972	to	4.177	.000***
	Study group (VRS vs. control)	.072	.094	-.112	to	.257	.442
	Time point						
	T2 vs. T0	.172	.079	.018	to	.326	.028*
	T1 vs. T0	.069	.071	-.071	to	.208	.334
	Study group × time point						
	VRS ×[T2 – T0]	.005	.132	-.253	to	.263	.969
	VRS ×[T1 – T0]	3.940E-5	.126	-.247	to	.247	1.000
Confidence	Intercept	3.657	.052	3.556	to	3.759	.000***
	Study group (VRS vs. control)	-.211	.099	-.404	to	-.017	.033*

	Time point						
	T2 vs. T0	-.193	.080	-.349	to	-.036	.016*
	T1 vs. T0	-.080	.076	-.228	to	.069	.292
	Study group × time point						
	VRS ×（T2 – T0）	.507	.144	.225	to	.789	.000***
	VRS ×（T1 – T0）	.288	.134	.026	to	.549	.031*
Satisfaction	Intercept	3.919	.056	3.809	to	4.030	.000***
	Study group (VRS vs. control)	.056	.108	-.155	to	.266	.604
	Time point						
	T2 vs. T0	.264	.093	.082	to	.446	.005**
	T1 vs. T0	.211	.085	.044	to	.378	.013*
	Study group × time point						
	VRS ×（T2 – T0）	.084	.154	-.218	to	.385	.587
	VRS ×（T1 – T0）	-.099	.145	-.293	to	.275	.951
Attitude	Intercept	4.152	.064	4.028	to	4.277	.000***
	Study group (VRS vs. control)	-.061	.104	-.264	to	.142	.554
	Time point						
	T2 vs. T0	.230	.088	.057	to	.402	.009**
	T1 vs. T0	.188	.096	-.001	to	.377	.051
	Study group × time point						
	VRS ×（T2 – T0）	.090	.144	-.193	to	.372	.534
	VRS ×（T1 – T0）	.064	.147	-.224	to	.352	.662

T0: Pre-test; T1: Post-test; T2: the end of the semester

* $P < .05$ ** $P < .01$ *** $P < .001$

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Effectiveness of VRS on Student's Learning Attitude

The average scores of learning attitudes for all participants at three-time points were 4.13 ±.53 at T0, 4.34 ±.54 at T1, and 4.39 ±.51 at T2, showing a gradual increase in learning attitudes from the beginning of the course to the end of the semester. GEE analysis revealed a statistically significant regression coefficient at T2 compared with T0 (β = .230, P =.009; Table 4).

Student's Experiences and Perceptions with VRS Learning

Based on the interviews, the student's learning experiences were categorized into four themes: applied professional knowledge to patient care, enhanced infection control skills, demonstrated patient care confidence and participated in real clinical cases. The core theme is strengthening clinical patient care competences.

Theme One: Applied Professional Knowledge to Patient Care

The students described how they applied their learned infection control theories during the VRS teaching process, especially when entering and exiting the negative pressure isolation unit, which involved complex theories that needed to be remembered. Through VRS teaching, feedback, and

debriefing, the students could reflect on the content of infection control learning, deepening their professional knowledge in this area. Here are some illustrative comments from the students:

> *"I applied the sequence taught in class to patients in the VR setting," (S7)*
>
> *"Seeing the feedback on items I missed made me reflect on the class content," and "There's a lot to memorize in infection control theory, but after using VR, it became easier to understand what the theory was about." (S2)*

Theme two: Enhanced Infection Control Skills

The students shared their experiences using VRS to execute care skills learned in the infection control unit. Through hands-on practice and observing fellow classmates, they found that their skills improved. Additionally, the students mentioned that the course's practical and interactive scenarios enhanced their learning interest and translated into learning outcomes. Some students expressed their thoughts as follows:

> *"I prefer courses with practical elements, and using VRS helped me better remember the procedures." (S4)*
>
> *"I personally operated it and observed my group members playing, along with the teacher's explanations, so the sequence of entering and exiting the negative pressure ward became very clear to me" (S11)*
>
> *"VRS is really suitable for courses requiring hands-on practice; practicing a few times makes one more skilled." (S8)*

Theme Three: Participated in Real Clinical Cases

The students who elected the integrated care course in emergency and critical care mostly hoped to have opportunities to intern or work in emergency departments or intensive care units. However, during the pandemic, many hospitals' critical care units stopped accepting nursing interns, or students were unable to participate in the care of patients with infectious diseases during their ward internships. The students suggested that through realistic scenario-based case studies, they could practice clinical skills unavailable in their practical training using VRS, bridging the gap between theory and practice. Operating VRS allowed them to provide care for simulated patients in a context closely resembling clinical settings, enhancing their learning experience. Here are some comments

from the students:

> *"I always wanted to work in emergency and critical care units. Having the opportunity to learn about the care of COVID patients through VR really bridges the gap with clinical practice." (S5)*
>
> *"Once you put on the (VR) headset, it feels very real, as if you are actually caring for a COVID patient." (S10)*
>
> *"I never thought I would get a chance to care for COVID patients before graduating, but with VRS, I could realistically simulate entering and exiting a negative pressure ward. (S3)*

Theme Four: Demonstrated Patient Care Confidence

During the interviews, the students expressed concerns about their future clinical care abilities due to the impact of the pandemic. They participated in VRS courses and noted increased confidence in providing patient care, and the realistic scenarios helped internalize their knowledge, thus boosting their confidence in patient care. The following are some examples of students' learning experiences:

> "*Some theories are hard to remember, but VR teaching has made me less afraid of caring for patients in negative pressure wards in the future." (S12)*
>
> *"During the pandemic, I worried about caring for COVID patients when I started practicing, but now I feel it shouldn't be difficult" (S1)*
>
> *"After experiencing VR, my fear of caring for COVID-19 patients significantly decreased, which is very important to me." (S13)*

Core Theme: Strengthening Patient Care Competences

The core theme of the qualitative study on students' learning experiences of engagement on VRS teaching is the deepening of clinical care competence. VRS learning program enables students to apply the professional knowledge and skills learned in the course to design patient scenarios. Through VRS practical exercises, the students improve the skills needed to care for patients with infectious diseases. Using clinical cases and performing learning tasks in a realistic setting enhances students' confidence in caring for patients with infectious diseases. This connection in learning experiences consequently deepens their clinical care competence, preparing them for the future care of patients with infectious diseases and showcasing the experiences and outcomes of students' learning in VRS scenarios

Discussion

Principal Findings

The results of this study demonstrated significant improvements in infection control knowledge scores in both groups, with the VRS group scoring higher, indicating the effectiveness of VRS teaching in enhancing theoretical knowledge. The VRS group also had higher learning motivation scores at T1 and significantly higher at T2. Post-course satisfaction scores were significantly higher for all participants compared with pre-course scores, although no significant difference was noted between the VRS and control groups. Students' learning experiences and perceptions of the VRS teaching included applying professional knowledge to patient care, enhanced infection control skills, demonstrating patient care confidence, participating in real clinical cases, and strengthening clinical patient care competencies.

Comparison with Prior Work

Effectiveness of Engagement VRS Teaching in Infection Control Knowledge

Systematic review and meta-analyses on VR in nursing education have shown its effectiveness in improving knowledge.[5,32] Another review stated a moderate effect size (g = 0.47) for VR teaching in knowledge learning,[33] similar to our study's outcomes. Each student participated in the VRS teaching for 6–8 min, applying infection control knowledge in a negative pressure isolation unit. Continued practice was allowed for those wishing to deepen their skills. An integrative review concluded that VRS teaching effective in acquiring clinical skills and knowledge.[34] An extensive review involving 29 RCTs with 2722 students found that VR, AR, and mixed reality are as effective as traditional methods in enhancing knowledge and play a significant role in preclinical education methods in enhancing knowledge and play a significant role in pre-clinical education.[35] Similarly, a German study on tracheal suction skills observed no statistical differences in knowledge and skills improvement among different teaching methods, suggesting VR as a supplementary resource for

existing learning strategies to assist students in teaching for clinical practice.[23]

Impact of VRS Teaching on Student Learning Motivation and Attitude

A systematic review and meta-analysis of 26 studies revealed no significant impact of VR on nursing students' motivation and cognitive load compared with traditional teaching.[36] This aligns with our study, which showed no significant difference in learning motivation. However, other studies have indicated higher motivation and satisfaction with VR, though it may also increase cognitive load.[37] VR positively impacts learners' attention and motivation, builds self-efficacy, and reinforces learning confidence and performance.[5,21,25,38] A Taiwanese study on nasogastric tube feeding indicated nonsignificant higher scores in the VR group. The VR group exhibited higher motivation and satisfaction but also higher cognitive load, suggesting the need to address cognitive load in future course designs.[37]

A South Korean study reported higher neonatal resuscitation knowledge, motivation, problem-solving skills, and confidence in the VR group compared with control groups, with lower anxiety levels.[26] An integrative review on VR teaching for emergency patients revealed increased confidence in handling emergencies.[25] Despite some studies finding no significant differences in anxiety and confidence,[3,39] further research is required to determine VR's impact on learning confidence and stress. A Chinese study on disaster nursing courses indicated significant improvements in preparedness, confidence, and performance in the experimental group, highlighting VR's potential as a cost-effective simulation method. [40] Technical issues with VR were noted as disadvantages, possibly explaining lower pre-course confidence in the VRS group compared with the control group. Ensuring students can operate VR systems before courses may improve confidence.[1,27,41-42]

Experiences and Perceptions of VRS Learning Experiences

The qualitative results of this present study revealed that the students' experiences and perceptions of VR learning experiences include applied professional knowledge to patient care, enhanced infection control skills, demonstrated patient care confidence, participated in real clinical

cases and core theme is strengthening clinical patient care competences. Studies have demonstrated that qualitative results related to VR indicate impacts on knowledge,[23,24,42] skills,[21,23,24] confidence,[23] and engagement.[4] However, several studies have presented the qualitative results of VR learning as a tool or focused on the characteristics of the VR environment.[21,22,42] By contrast, the present study applied phenomenography to explore students' experiences and perceptions in VRS learning.

Strengths and Limitations

The strength of this study lies in its comprehensive approach, combining both quantitative and qualitative methods, providing a well-rounded understanding of the VRS teaching effectiveness. However, this study has some limitations to consider. First, the sample size, although adequate, might not fully represent the diversity of nursing students due to only being in one university. Second, the study's duration did not allow for assessing long-term learning effects. Third, the control group used practical exercises for donning and doffing isolation gowns, differing from traditional nursing classroom teaching methods used in past studies. Future studies should expand on the applications of VRS in nursing education to more comprehensively elucidate the effectiveness of such programs.

Conclusions

This study highlights the effectiveness of the VRS teaching for undergraduate nursing students in enhancing infection control knowledge, learning motivation, attitudes, and course satisfaction. Qualitative insights further support the quantitative findings, suggesting a holistic outcome of VRS in nursing education. Despite its limitations, this study opens avenues for future research and presents a compelling case for the broader implementation of VR in nursing education curricula. Further studies should consider longitudinal designs to evaluate the long-term impacts of VRS teaching on nursing education. Additionally, expanding the participant pool to include a more diverse range of students could provide more generalizable results. The findings have significant

implications for nursing education, suggesting that the VRS teaching can effectively enhance learning outcomes, particularly in areas requiring high practical knowledge and skill levels. The positive impact on student motivation and attitudes also indicates a potentially transformative shift in how nursing education can be delivered, especially in a post-COVID-19 era where digital and remote learning tools are becoming increasingly important.

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Supplementary Files

Related publication(s) - for reviewers eyes onlies

Appendix_Interview Guide.
URL: http://asset.jmir.pub/assets/661ffd0218429161becf9c306c223bf4.pdf