GAMES FOR HEALTH JOURNAL: Research, Development, and Clinical Applications
Volume 14, Number 2, 2025

DOI: 10.1089/g4h.2023.0139

The Effectiveness of Immersive Virtual Reality Simulation as an Innovative Learning Strategy for Acquisition of Clinical Skills in Nursing Education: Experimental Design

Samar Thabet Jallad, Assist. Prof.[1] and Burçin Işık, Assist. Prof.[2]

Abstract

Background: A transformation of learning in nursing is necessary to prepare students for developing complex clinical environments. The essential aim of clinical nursing learning is to enhance the integration of theoretical knowledge in the clinical environment by using various innovative strategies, such as immersive virtual reality (VR) simulation to develop a learning process that allows students to gain knowledge and perform skills in a visually attractive way, which enhances the quality and safety of clinical learning through repeated exposure to educational content that supports students' cognitive and psychomotor skills.
Objective: This study was aimed at determining the effectiveness of immersive VR simulation as a learning strategy on the acquisition of intramuscular injection skills in nursing education and the performance level of nursing students compared with a physical learning environment (low-fidelity simulation).
Materials and Metods: The experimental design (pre–post-test) was used among first-year nursing students ($N = 66$) (control group = 33, hip model and experimental group = 33, VR simulation) of the summer semester of 2019–2020 in the Faculty of Nursing at Near East University in Cyprus.
Results: There is a significant difference between both groups in performance psychomotor skills scores, and the mean was higher in the experimental group ($P = 0.002$) and a significantly longer period of time than in the control group ($P < 0.05$).
Conclusion: Immersive VR simulation is a supplementary tool and useful teaching-learning strategy for training in nursing education alongside physical laboratory (hip-model and mannequin) and psychomotor skills requiring the ordering of skill steps in teaching, and it provides realistic experiences in a safe environment instead of the unavailability of actual customers in clinical settings.

Keywords: Virtual reality simulation, Immersive virtual reality simulation, Physical learning, Learning strategy, Nursing education, Undergraduate students

Introduction

Learning in an active and effective instructional environment is based on challenges and learning objectives.[1] The essential aim of clinical nursing learning is to enhance the integration of theoretical knowledge in clinical practice[2] by using various modern and innovative strategies that are suitable for the demands of the digital age.[3]

Traditionally, learning in nursing education provided a form of theory-based lectures, with structured clinical hours undertaken in the clinical environment within physical laboratories.[4,5] Since the mid-2000s, the transfer into the digital age has seen a move into blended learning methods, which are constructive and consist of several learning strategies, such as audio-visual elements, online learning, and self-directed learning skills.[6]

[1]Department of Nursing, Faculty of Health Professions, Al-Quds University, Jerusalem, Palestine.
[2]Department of Nursing, Faculty of Health Sciences, Gaziantep İslam Science and Technology University, Gaziantep, Turkey.

In a clinical learning setting, using virtual reality (VR) simulation as a teaching tool can narrow the knowledge gap between theory and practice,[7] which may contribute to reducing the impact of mistakes made in clinical settings.[8]

Background

In nursing education, the development of skills in the laboratory setting forms the foundation of safe patient care.[9] Inexperienced students are at risk of causing harm when they learn and practice these skills on the patient.[10] In the physical laboratory environment, low-fidelity simulations use devices such as partial task trainers or full-body mannequins, or high-fidelity simulations use devices such as instructor-controlled computerized mannequins to practice and gain psychomotor skills that act on a body part, such as an anatomical structure or extremity,[11] which lets the learner focus on an isolated task and improves the acquisition of knowledge and skills.[12]

In recent days, VR is one of the most common methods of simulation and has become an effective supplementary tool for instruction[13] that is based on computer technology to form a cooperative three-dimensional (3D) world in which handlers have a sense of immersion.[14] So, immersive VR simulation is defined as a feeling of being physically present in a non-physical world created with images, sound, or other stimuli around the user of the VR system, giving the participants the impression that they are truly "there."[15]

The essential aim of learning via VR is to present students' experience and engagement in cooperative learning through multidisciplinary and professional group working simulations.[16] In addition, VR simulation enhances abilities and learning skills that enable educators to deliver knowledge in a visually attractive way that contributes to developing the quality and safety of clinical learning through repetitive exposure to educational content that promotes cognition and psychomotor skills among learners.[17–19]

In light of these explanations, and to assess the effectiveness of VR simulation as a learning strategy in the clinical learning environment on performance students, this study used the low-fidelity simulation on the hip model, and immersive VR simulation (VR Oculus Quest, head-mounted and tracking gloves); using intramuscular (IM) injection skill application, which is one of the core skills in a Fundamentals of Nursing course, to provide educators vital evidence that supports the transformation of clinical education and improves learners' performance in a safe learning environment.

This study was conducted to examine the effectiveness of immersive VR simulation as a learning strategy for the acquisition of IM injection skills in nursing education and the performance of nursing students' levels

Materials and Methods

Study design

An experimental study was conducted (pre–post-test).

Setting

The study was conducted in the Nursing Faculty at Near East University of the Turkish Republic of North Cyprus (TRNC), from August 10 to September 20, in the summer semester of the 2019–2020 academic year.

Sampling and participants

The whole population was 220 first-year students, who enrolled in the "Fundamentals of Nursing" course for the first time at the Near East University Faculty of Nursing in the summer semester of the 2019–2020 academic year. The sample population was calculated by using the sample size calculation formula: **Sample Size = n/[1 + (n/population)]; In which n = Z × Z [P (1 − P)/(D × D)],* and it consisted of $N = 66$ participants for an error rate less than 0.10 and a confidence level of 90%.[20] Also, the sample size was confirmed by using G*Power3 program, a flexible statistical power analysis program for the social, behavioral, and biomedical sciences.[21] Taking into consideration that the students included in the experimental and control groups entered the laboratory for the first time, the sample was assigned by using the sampling approach using odd (33 control group; hip injection model) and even (33 experimental group; VR simulation) numbers.

*Population Value = 220
P = Expected Frequency Value = 10%
D = (Expected Frequency-Worst Acceptable) = 17.2%
Z = 1.28 with a confidence level of 90%
Formula: $\text{Sample Size} = n/[1 + (n/\text{population})]$
In which $n = Z * Z\left[P(1 - P)/(D * D)\right]$
First, calculate the value for "n".

$$n = Z \times Z\left[P(1-P)/(D \times D)\right]$$

$$n = 1.28 \times 1.28 \times \left(0.172 \times (1 - 0.172)/(0.05 \times 0.05)\right)$$
$$n \approx 93$$

Next, calculate the sample size (S = sample size).

$$S = n/[1 + (n/\text{population})$$

$$S = 93/[1 + (93/220)]$$
$$S \approx 66$$

Inclusion criteria

The students who had no experience in IM injection and preparing medication from an ampule and similar invasive administrations without this course. Also, the students who had enrolled in a fundamental nursing course for the first time in the English language.

Exclusion criteria

All of the students who had not taken a fundamental nursing course in English, and who repeated this course more than once.

Data collection instrument

Sociodemographic instrument. This instrument gathered the descriptive sociodemographic characteristics of participants and was designed by the researcher as questions, such as: gender, age, grade point average (GPA), and whether students had a personal computer and education about computer/computer software.

IM ventrogluteal injection skill checklist. It was used to collect data on students' IM ventrogluteal injection skills and prepared by the researcher based on the *Fundamentals of Nursing 9th edition*[22] to evaluate the skills performance level of students, listing 37 steps in the IM ventrogluteal injection procedure. Each step in the form was scored as done (1) or not done (0). Although the highest possible score to be obtained is 37, the lowest possible score is 0. Higher scores indicate higher IM ventrogluteal injection skill levels.

In addition, this checklist was used by the researcher and two observers, who are educators and specialized in the fundamental and surgical department in the nursing faculty, to assess students who administered the IM injection to determine the level of their psychomotor performance skill. The inter-rater reliability between the researcher and two observers was measured by taking the average of the researcher and two observers, the consistency between the researcher and the observers was accepted as the reliability of the measurement, Cronbach's alpha value of the "Intramuscular Ventrogluteal Injection Skill Checklist" in the pre-test for the control group and the experimental group was calculated as 0.74 and 0.72; respectively, in post-test for both groups (0.78), and, in an actual patient in all of the control group and the experimental group, the reliability was (0.75, 0.76; respectively). The Cronbach's alpha within the range of 0.70–0.95 was accepted as satisfactory for internal consistency.[23] In addition, the Pearson correlation coefficient was used to examine the correlation between the data collected the first and second time.[23] There is a significant correlation between the researcher and observers in the control group ($r = 0.756–0.911$; $P < 0.05$), and in the experimental group ($r = 0.786–0.871$; $P < 0.05$) in the pre–post-test and an actual patient.

Study procedure. Following approval from the research ethics committee to conduct this study at the nursing faculty's fundamental nursing laboratory for all participants, the researcher went over the purpose of the research and the IM injection procedure. She also gave them an overview of all the instruments used in the VR Quest, such as the head-mounted and tracking gloves. In addition, hip models, syringes, and needles. She then used the sampling approach using odd (control group) and even (VR simulation group) numbers to separate them into two groups. In addition, a time frame was set for each group to start the study, with the control group starting first.

The enhanced injection hip model (control) group consisted of three groups, each with 11 participants. The groups were conducted over a three-week period under the supervision of the researcher and two observers (pre–post-test, and on an actual patient). The model is similar to the real human hip and is used in professional skill laboratories to help learners develop their skills[24] (see Fig. 1).

VR simulation (Experimental) group; following confirmation of the IM injection application installation in VR Oculus Quest, demonstration of this strategy by a desktop computer for all participants, and instruction on how to wear and use tools, the researcher separated the participants into four groups. Eight to nine participants per group participated one by one over a four-week period (pre–post-test and on an actual patient) under the supervision of the researcher and two observers (see Figs. 2 and 3).

Ethical Consideration

Before the recruitment of participants and the start of data collection, expedited review and approval by the university institutional review board (IRB) were obtained (Approval #YUD/2020/76–985). Students were informed that there would be no personal direct benefits to participation and assured that participation in the study was entirely voluntary, without any consequence related to their grades. Thus, informed consent was obtained from students before participation in the study.

Data Analysis

Data were analyzed by using SPSS Statistics version 25 for Windows (Statistical Package for the Social Sciences). Frequency percentages, arithmetic means, standard deviation values, and chi-square test were used to analyze the

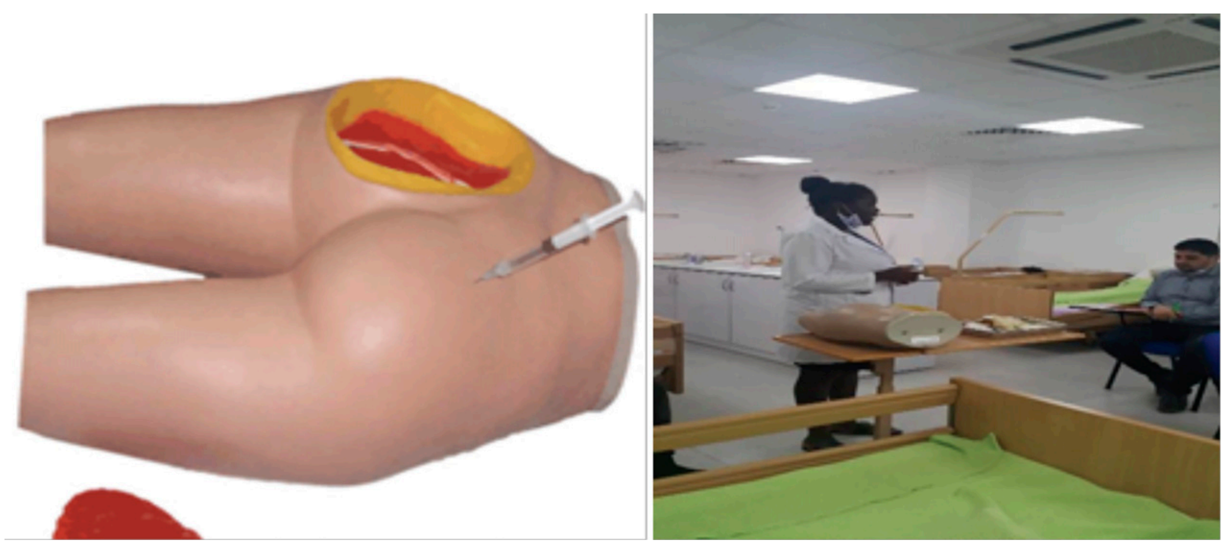
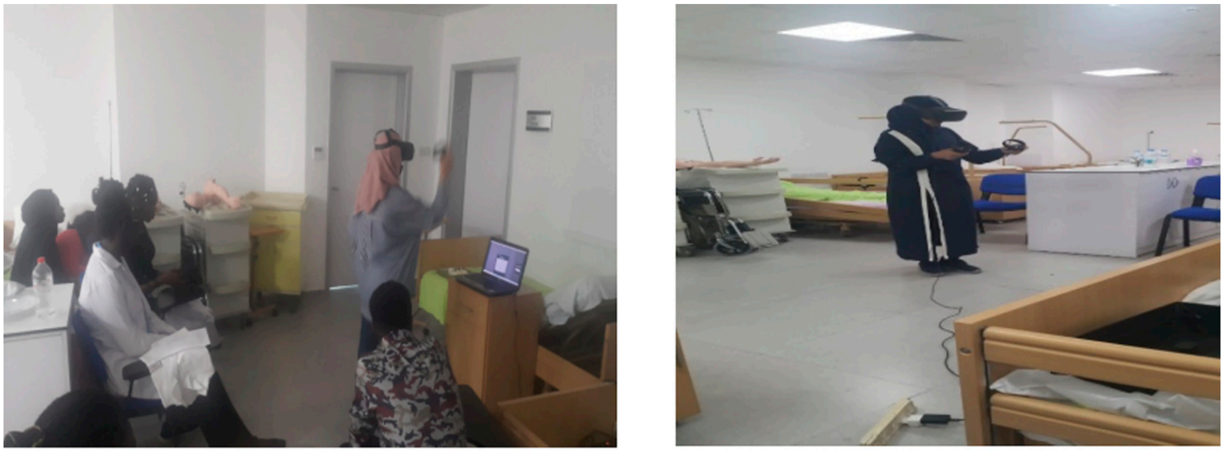


FIG. 1. Students perform skill in the injection hip model.



(a) (b)

FIG. 2. **(a)** Researcher-introduced skill on VRS; **(b)** student-performed skill on VRS.

descriptive statistical evaluation of demographic data. A paired-sample test was used to examine the consistency, correlation, and reliability of a checklist of IM injection skills (37 items) between observers.

To validate the instrument, for data distribution, the Shapiro–Wilk test of normality was less than 0.05. So, a nonparametric test (Mann–Whitney U test) was used to assess the difference between and among the groups (pre-test, post-test, and an actual patient). In addition, independent *t test* was used to compare means of time between the two groups, and repeated-measures ANOVA with Bonferroni correction (Greenhouse–Geisser test) was used to assess time performance that was spent within group three times (pre-test, post-test, and on an actual patient).

Results

Sociodemographic characteristics of the students

There was no statistically significant difference ($P > 0.\ 05$) between the experimental and control groups in terms of "age, gender, mean professional course grade point average, and having a personal computer." Groups were similar in terms of these characteristics. 36.4% of the control group's age ranged between 21 and 24 years, 66.7% were female, the professional course grade point average was successful, 33.3% had a CB (Good) grade, a score of 70%–79% (Near East University grade system), and 54.2% had a personal computer.

57.6% of the experimental group's age ranged between 17 and 20 years, 66.7% were female, the professional course grade point average was successful, 36.4% had a BA grade (Very good), a score of 85–89%) (Near East University grade system), and 52.4% did not have a personal computer (see Table 1).

Performance psychomotor skill scores

There was a statistically significant difference between the groups in the pre-test and an actual patient ($P < 0.05$). In addition, the mean of performance in the experimental group (pre-test 34.08 ± 3.90, post-test 31.73 ± 2.81, and with an

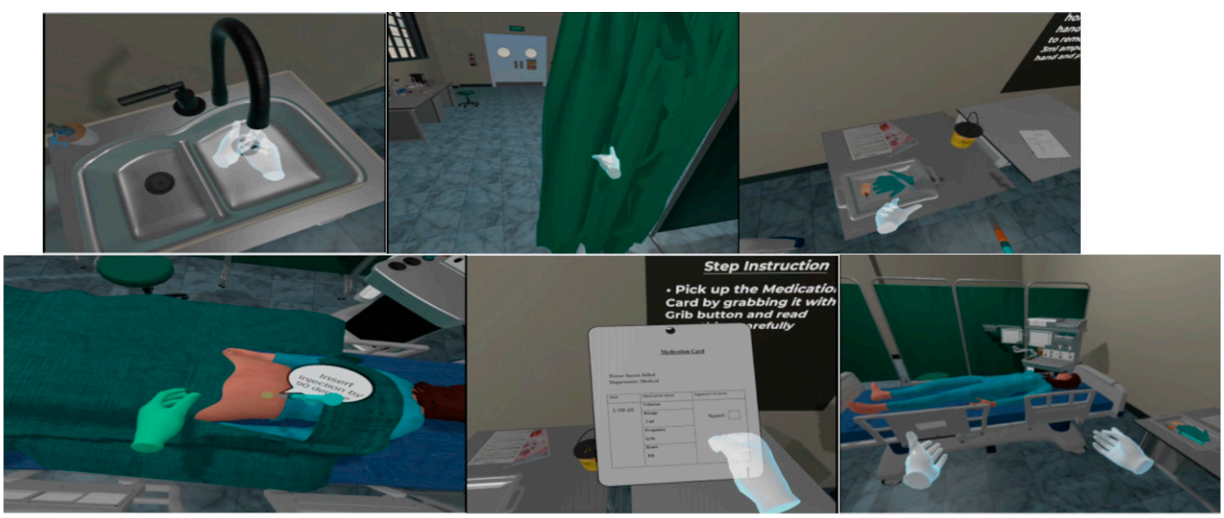


FIG. 3. Intramuscular injection steps (Gesture & Avatar).

TABLE 1. DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS IN BOTH GROUPS ($N = 66$)

		Experimental group		*Control group*		*Total*			
Variable	*Category*	n = *33*	*%*	n = *33*	*%*	n = *66*	*%*	X^2	P *value*
Age group	17–20	19	57.6	11	33.3	30	45.5	3.93	0.14+
	21–24	8	24.2	12	36.4	20	30.3		
	≥25	6	18.2	10	30.3	16	24.2		
Gender	Male	11	33.3	11	33.3	22	33.3	.000	1.00
	Female	22	66.7	22	66.7	44	66.7		
GPA	AA	0	0	2	6.1	2	3.05	6.59	.36+
	BA	12	36.4	7	21.2	19	28.8		
	BB	8	24.2	10	30.3	18	27.3		
	CB	10	30.3	11	33.3	21	31.8		
	CC	3	9.1	1	3.0	4	6.1		
	DD	0	0	1	3.0	1	1.5		
	FD	0	0	1	3.0	1	1.5		
Have a personal computer	Yes	11	45.8	13	54.2	24	50	.26	0.61
	No	22	52.4	20	47.6	42	50		

Grade Point Average (GPA); X^2 = Chi-square test.

actual patient 32.84 ± 2.78) was higher than in the control group (see Table 2).

Performance psychomotor skill time score

A repeated-measures ANOVA was conducted comparing the differences in average time, pre, post, and actual "within-subjects factor" and by the group "between-subjects factor." The group variable was entered as a between-level factor. The primary purpose of repeated-measures ANOVA was to detect if the interaction between those two independent variables was significant.

Before conducting the repeated-measures ANOVA, the major assumptions were checked, including the continuous dependent variable, the between-group factor (group) having at least two categories, no significant outliers, and normally distributed outcome scores for each group.

The sphericity assumption was violated as indicated by Mauchly's test of sphericity = 0.791, $P = 0.001$. Therefore, Greenhouse–Geisser was used to test the within-subjects time effects. The F tests determined that there is a statistically significant effect over time (pre-test vs. post-test vs. actual patient) in mean scores of time [$F(1.6, 64) = 151.145$, $P < 0.001$]. The effect of the intervention across time and group was tested by the repeated-measures ANOVA interaction effect of time and group. The results showed that there is a significant group by time interaction, Greenhouse–Geisser ($F(1.6, 64) = 101.881$, $P < 0.001$).

The findings showed that the mean performance time in the control group was significantly shorter than in the experimental group (pre-test = 11.79, post-test = 8.81, actual patient = 9 minutes; pre-test = 38.67, post-test = 22.24, actual patient = 9.2 minutes; respectively). Within groups, the mean performance time in actual patient and post-test was shorter than the pre-test in the experimental group (pre-test vs. post-test = 16.42; pre-test vs. actual patient = 29.39; post-test vs. actual patient = 12.97 minutes) ($P < 0.001$) (see Table 3 and Fig. 4).

Discussion

Understanding the procedural step-by-step process is an important condition for successful execution. Through skill acquisition theory, learning skills include the cognitive skills that are essential to carrying out a skilled performance of a sequence.[19,25] Through experiential learning, learners practice and improve their performance based on what they know until effective patterns of performance appear.[26] Consequently, VR simulation lets experiential learning and error training occur.[27]

Performance knowledge skill scores

In this study, VR simulation provides various case scenarios and realistic complications and thus allows students to

TABLE 2. COMPARISON OF CONTROL AND EXPERIMENTAL GROUP STUDENTS' PERFORMANCE PSYCHOMOTOR SKILL

	Experimental group (n = *33*)		*Control group* (n = *33*)		
Group	*Test*	*Mean ± SD*	*Mean ± SD*	Z^a	P *value*
Performance psychomotor skill					
	Pre	34.08 ± 3.90	31.17 ± 3.46	−3.130	**0.002****
	Post	31.73 ± 2.81	30.15 ± 3.86	−1.420	0.15
	Actual patient	32.84 ± 2.78	31.01 ± 3.51	−2.208	**0.020***

[a]Mann–Whitney U test.
*$P < 0.05$. **$P < 0.001$.

Table 3. Comparison of Control and Experimental Group Students' Performance Time

	Test	*Experimental group (n = 33) Mean ± SD*	*Control group (n = 33) Mean ± SD*	*Lower-Upper 95% CI (control group)*	*Lower-Upper 95% CI (experimental group)*	t	*P value (between group)
Performance time (Min.)	Pre	38.67 ± 11.13	11.79 ± 3.68	10.48–13.09	34.72–42.61	26.88	**0.001***
	Post	22.24 ± 7.62	8.82 ± 2.07	8.09–9.55	19.54–24.94	13.42	**0.001***
	Actual patient	9.273 ± 2.09	9.00 ± 2.95	7.96–10.05	8.53–10.02	0.27	0.990
**P value (within group)		**0.001****	**0.001****	F = 101.881			

*Independent *t test* between groups ($P < 0.001$).

**Repeated-measures ANOVA test (Greenhouse–Geisser) within groups, performed three times ($P < 0.00$).

develop cognitive and psychomotor skills related to IM injection skills, which agreed with the study of Ismailoglu & Zaybak,[28] which showed higher scores in the experimental group that addressed virtual intravenous simulator necessary for intravenous interventions than in the control group, which practiced the plastic arm model.[28] In addition, it is consistent with studies by Boada et al.[29] and Tsai et al.[30] that indicated VR simulation utilized in several skills, such as suctioning, chronic obstructive lung disorder, postoperative morphine treatment, cardiopulmonary resuscitation, and advanced life support game-based VR application ($P < 0.05$).[29,30] Furthermore, VR simulation has features that allow students to obtain information at their own pace, using both visual and auditory sensory channels to process related information leading to better learning. Thus, it helps focus students' attention on suitable tasks in practical environments.[26]

In this study, the pre-test results for the skill of administering IM injection in the ventrogluteal site showed a significant difference ($P < 0.05$) in the experimental group. This is likely because learners can perform this skill by watching the demonstration and repeating steps by observing and noticing the most critical points related to it, such as defining medication rights, identifying the correct site of injection, and performing skills in an orderly manner. This finding is consistent with a study by Bayram and Caliskan[31] that found that students in the experimental group had higher levels of inner cannula cleaning ($P = 0.000$) and peristomal skin care ($P = 0.033$) than those in the control group. These procedures are less difficult than other skills and can be learned by watching the demonstration and repeating the steps only once.[31]

In this study, according to the students, the VR skill learning system allowed them to view the operating method on the overhead checklist. Students might learn and comprehend where errors were made by carefully following the process step-by-step. The system used alerts to promptly warn students of their mistakes as they conducted procedures, a similar study is that of Yu and Chin (2021), which showed performing the entire procedure understandable to students who were

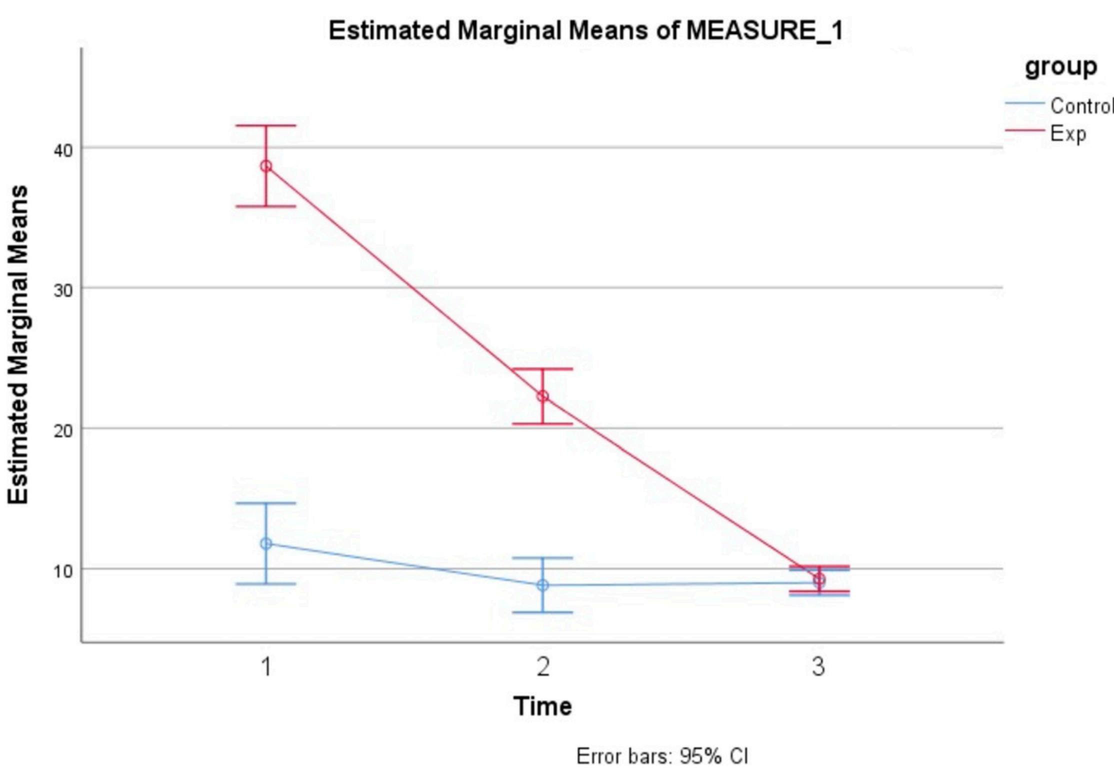


FIG. 4. Students' performance time within groups 3 times (pre- test, post-test, actual patient) (Greenhouse–Geisser test).

unfamiliar with the technology, and assisting them in making more accurate movements throughout training. VR apps for nursing skill teaching provide immediate student feedback and limitless access to nursing skill training, which lowers mistakes in caregiving and enhances the standard of care.[19] In addition, the study of Ismailoğlu and Zaybak[28] and Seo et al.[32] showed there was no statistical significance between the experimental and control groups in terms of pre-test and post-test in the knowledge scores related to IV catheterizations, because both groups were applying relevant theoretical knowledge and then performed the IV catheter intervention steps in the laboratory several times as they wanted, which may have enhanced the knowledge of all participants.[28,32] Thus, teaching psychomotor skills is an important process that comprises transferring students' theoretical knowledge to practice and developing their performance skills.[31]

In this study, there was a statistically significant difference between the groups in an actual patient ($P < 05$) that there was a higher mean score in the experimental group, which agreed with the study of Vidal et al.[33] that indicated that those trained on the simulated limbs performed better and produced significantly fewer hematomas when they attempted phlebotomy skills on actual patients.[33] Thus, these findings showed that VR simulations are an efficient teaching-learning strategy in clinical environments, because they are nearby models of reality, allow practice without harming the patient, and provide a free learning environment that allows for mistakes in this environment. As well as it is beneficial in performing psychomotor skills, particularly in clinical learning.[34,35]

In this study, it was noticed that both methods of training, whether hip model injection or VR simulation, are not perfect by themselves and do not completely represent the IM injection skill as performed on patients. For example, neither the hip model injection nor the VRS provide a challenge in the placement of the site or the selection of the insertion site. Moreover, those trained using the VR simulation tools can easily choose the ventrogluteal site through palpating by tracking gloves. So, VR simulation, through the use of several applications of skills, is useful in teaching psychomotor skills and is considered a supplementary tool for learning strategies. Thus, students who have higher performance scores also have a high level of readiness to apply this innovative technique.[7]

Performance psychomotor skill time

In this study, significant differences were shown in the pre–post-test ($P = 0.001$). Due to the immaturity of VR technology when students used it for the first time and their lack of prior experience with virtual simulation systems, the control group's mean performance time scores to complete all steps of the IM procedure were shorter than those of the experimental group. These findings are consistent with studies conducted by Bayram and Caliskan[31] and Vidal et al.,[33] which reported a gap between completing virtual cases and real practice in skills.[31,33,36] Also, it agrees with the study by Butt et al.,[37] which showed students using the VR system in urinary catheterization spent more time practicing ($P = 0.001$) and completed more procedures in 1 hour than students who practiced traditionally ($P < 0.001$). Follow-up skill demonstration pass rates between groups were identical at two weeks to enhance mastery learning and retention.[37] Furthermore, it can be associated with technological problems such as network disconnections and restricted device charging that are not present in hip model injection. This did not imply that learning outcomes with VRS declined; rather, the best course of action for educating nursing students may involve using a VR-based system as a complement to the traditional approach.[38]

This study showed significant differences in performance time within groups in all of the tests, it is observed clearly in the experimental group in all of the tests, which agreed with the studies of Smith et al.[39] and Jung et al.,[40] which indicated performing skills by using VR simulation is easy to complete in order and without error in lesser time.[40,41] This confirms that the VR simulation strategy is considered an accessible learning environment by allowing repetitive exposure to educational content to develop cognitive and skill mastery among students, which increases their competency to perform skills and provides patient safety.[18,39,42] Also, students will learn faster by having experience with the action, previous knowledge, and familiarity, improving retention of skill in procedural memory.[43]

Limitation

This study was carried out at Near East University; it was limited to 66 first-year students at the Faculty of Nursing who participated in this study, and the research results cannot be generalized. Future research should replicate this study with randomly selected larger sample sizes from different regions to minimize the limitations of this study. It would also be beneficial to include teachers to address any possible differences between the two groups and integrate different variables such as satisfaction, self-efficacy, self-directed learning, and anxiety, which would require interpretation from a different point of view. Moreover, the survey instrument should be enhanced by researchers to assess students' actual application of VR technology, even after its validity and reliability have been tested.

Conclusion and Recommendation

This study concluded that immersive VR simulation technologies in educational VR applications can be used as a promising learning tool for nursing education through the design of different VR applications based on a specific learning theory and nursing psychomotor skills, especially those that require procedural and practical knowledge. On the contrary, it is considered a type of VR simulation that can be used as a supplementary tool for learning strategies for clinical learning in several skills alongside the physical laboratory learning environment to acquire psychomotor skills, retain knowledge, and improve learners' satisfaction and self-efficacy in a safe real learning environment.

This study serves to provide insights for future improvements, especially for VR application developers and educators in several education fields, particularly nursing education. Therefore, this study recommended that educators, faculties, universities, and policymakers in education communities improve and develop the undergraduate curriculum of clinical education by inserting and merging innovative strategy methods such as VR simulation into various practical skills that lead to increased student performance by letting the indefinite implementation of clinical scenarios in a risk-free environment, which contributes to achieving learning objectives and increasing learning outcomes through the motivation and success of the student. Also, it seeks to perform experimental quantitative and qualitative research associated with VR technologies and platforms.

Implication of Nursing Education/Practice

This study contributes to the application of VR technology in several educational medical fields, particularly nursing education and clinical settings. Also, it is considered empirical evidence indicating its potential benefits for students' nursing learning regarding nursing skills such as IM injection skills. On the contrary, this study assists in designing various applications for different nursing and medical procedures that have the potential for educational uses in classrooms. Moreover, in this study, the researcher and an IT specialist designed, developed, and implemented an immersive VR simulation-based teaching platform containing a set of IM injection skills that students can engage in with head-mounted displays in classrooms and laboratories, which can improve students' academic achievement, performance, and engagement. Consequently, this study may contribute to the sharing and cooperation of multidisciplinary fields such as IT, engineering, and several education and medical fields.

Acknowledgments

The authors would like to thank Fiver company (www.fiver.com) for coding the simulation software to the virtual environment, Tamkeen Organization, Prof. Mahmoud Haddad, and Saeed AL-Hmoud for their contributions for technical support.

Author Disclosure Statement

Conflict of interests not available.

Funding Information

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

1. Zou D, Huang Y, Xie H. Digital game-based vocabulary learning: Where are we and where are we going? Comput Assist Lang Learn 2021;34(5–6):751–777; doi: 10.1080/09588221.2019.1640745
2. Heinonen AT, Kääriäinen M, Juntunen J, et al. Nursing students' experiences of nurse teacher mentoring and beneficial digital technologies in a clinical practice setting. Nurse Educ Pract 2019;40:102631; doi: 10.1016/j.nepr.2019.102631
3. Kavanagh JM, Sharpnack PA. Crisis in competency: A defining moment in nursing education. Online J Issues Nurs 2021;26(1); doi: 10.3912/OJIN.Vol26No01Man02
4. Tierney O, Sweet L, Houston D, et al. A historical account of the governance of midwifery education in Australia and the evolution of the continuity of care experience. Women Birth 2018;31(3):e210–e215; doi: 10.1016/j.wombi.2017.09.009
5. Berger-Estilita J, Meço BC. Simulation-Based learning: Basics for Anaesthetists. Turk J Anaesthesiol Reanim 2021; 49(3):194–200; doi: 10.5152/TJAR.2020.1203
6. Ragazzi F. Students as suspects. The challenges of counter-radicalisation policies in education in the Council of Europe member states. Council of Europe: Strasbourg, France; 2018.
7. Jallad ST, Işık B. The effectiveness of virtual reality simulation as learning strategy in the acquisition of medical skills in nursing education: A systematic review. Ir J Med Sci 2022; 191(3):1407–1426; doi: 10.1007/s11845-021-02695-z
8. Yu M, Mann JS. Development of virtual reality simulation program for high-risk neonatal infection control education. Clin Simul Nurs 2021;50:19–26; doi: 10.1016/j.ecns.2020.10.006,
9. Bayoumy HMM, Albeladi GA. Clinical judgment skills among junior-level nursing students enrolled in adult health nursing courses: Errors and risk level classification. Nurse Educ Pract 2020;48:102888; doi: 10.1016/j.nepr.2020.102888
10. Perry AG, Potter PA, Ostendorf WR, et al. Clinical nursing skills and techniques, 10th edition. Elsevier Health Sciences (E-book), 2021.
11. Cheung JJ. Knowing How and Knowing Why: Integrating Conceptual Knowledge in Simulation-based Procedural Skills Training to Support Learning Transfer. Thesis. TSpace, University of Toronto (Canada). 2019.
12. Franklin AE, Blodgett NP. Simulation in undergraduate education. Annu Rev Nurs Res 2020;39(1):3–31; doi: 10.1891/0739-6686.39.3
13. Shin H, Rim D, Kim H, et al. Educational characteristics of virtual simulation in nursing: An integrative review. Clin Simul Nurs 2019;37:18–28; doi: 10.1016/j.ecns.2019.08.002
14. Lioce L, Lopreiato J, Downing D, et al. Healthcare Simulation Dictionary –Second Edition. Agency for Healthcare Research and Quality: Rockville, MD, USA, 2020; doi: 10.23970/simulationv2
15. Freina L, Ott M. A literature review on immersive virtual reality in education: State of the art and perspectives. Proceedings of the 11th International Scientific Conference "eLearning and Software for Education" Carol I National Defence University Publishing House, Bucharest, Romania, 2015, pp. 133–141; doi: 10.12753/2066-026X-15-020
16. Huang HM, Liaw SS. An analysis of learners' intentions toward virtual reality learning based on constructivist and technology acceptance approaches. Irrodl 2018;19(1); doi: 10.19173/irrodl.v19i1.2503
17. Chen FQ, Leng YF, Ge JF, et al. Effectiveness of Virtual Reality in Nursing Education: Meta-Analysis. J Med Internet Res 2020;22(9):e18290; doi: 10.2196/18290
18. Rourke S. How does virtual reality simulation compare to simulated practice in the acquisition of clinical psychomotor skills for pre-registration student nurses? A systematic review. Int J Nurs Stud 2020 Feb;102:103466; doi: 10.1016/j.ijnurstu.2019.103466
19. Chang YM, Lai CL. Exploring the experiences of nursing students in using immersive virtual reality to learn nursing skills. Nurse Educ Today 2021;97:104670; doi: 10.1016/j.nedt.2020.104670
20. Lakens D. Sample size justification. Collabra: Psychology 2022;8(1):33267; doi: 10.1525/collabra.33267
21. Faul F, Erdfelder E, Lang AG, et al. G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 2007 May; 39(2):175–191; doi: 10.3758/bf03193146
22. Potter PA, Perry AG, Stockert PA, et al. Fundamentals of Nursing – Ninth edition. Mosby Elsevier, St. Louis, MO, USA; 2017.

23. Erefe İ. Veri toplama araçlarının niteliği. Hemşirelikte Araştırma İlke Süreç ve Yöntemleri, Odak Ofset, Ankara, Turkey; 2002, pp. 133–138.
24. Nasco Life Form. Advanced Injection Arm LF01121U& LF01126U, in Instruction Manual. 1982.
25. DeKeyser R. Skill acquisition theory. In. Theories in second language acquisition, Third edition. Routledge: Ellis, NC, USA; 2020, pp. 83–104.
26. Dubovi I, Levy ST, Dagan E. Now I know how! The learning process of medication administration among nursing students with non-immersive desktop virtual reality simulation. Comput Educ 2017;113:16–27; doi: 10.1016/j.compedu.2017.05.009
27. Asad MM, Naz A, Churi P, et al. Virtual reality as pedagogical tool to enhance experiential learning: A systematic literature review. Educ Res Int 2021;2021:1–17; doi: 10.1155/2021/7061623
28. İsmailoğlu EG, Zaybak A. Comparison of the effectiveness of a virtual simulator with a plastic arm model in teaching intravenous catheter insertion skills. Comput Inform Nurs 2018;36(2):98–105; doi: 10.1097/CIN.0000000000000405
29. Boada I, Rodriguez-Benitez A, Garcia-Gonzalez JM, et al. Using a serious game to complement CPR instruction in a nurse faculty. Comput Methods Programs Biomed 2015;122(2):282–291; doi: 10.1016/j.cmpb.2015.08.006
30. Tsai SL, Chai S, Chuang KH. The effectiveness of a chronic obstructive pulmonary disease computer game as a learning tool for nursing students. Ojn 2015;05(07):605–612; doi: 10.4236/ojn.2015.57064
31. Bayram SB, Caliskan N. Effect of a game-based virtual reality phone application on tracheostomy care education for nursing students: A randomized controlled trial. Nurse Educ Today 2019;79:25–31; doi: 10.1016/j.nedt.2019.05.010
32. Seo KT, Hwang HS, Moon LY, et al. Performance comparison analysis of linux container and virtual machine for building cloud. Netw Commun 2014;66:105-111; doi: 10.14257/astl.2014.66.25
33. Vidal VL, Ohaeri BM, John P, et al. Virtual reality and the traditional method for phlebotomy training among college of nursing students in Kuwait: Implications for nursing education and practice. J Infus Nurs 2013;36(5):349–355; doi: 10.1097/NAN.0b013e318243172f
34. Sabbagh AJ, Bajunaid KM, Alarifi N, et al. Roadmap for developing complex virtual reality simulation scenarios: Subpial neurosurgical tumor resection model. World Neurosurg 2020;139:e220–e229; doi: 10.1016/j.wneu.2020.03.187
35. Hu KC, Salcedo D, Kang YN, et al. Impact of virtual reality anatomy training on ultrasound competency development: A randomized controlled trial. PLoS One 2020;15(11): e0242731; doi: 10.1371/journal.pone.0242731
36. Succar T, Zebington G, Billson F, et al. The impact of the Virtual Ophthalmology Clinic on medical students' learning: A randomised controlled trial. Eye (Lond) 2013;27(10): 1151–1157; doi: 10.1038/eye.2013.143
37. Butt AL, Kardong-Edgren S, Ellertson A. Using game-based virtual reality with haptics for skill acquisition. Clin Simul Nurs 2018;16:25–32; doi: 10.1016/j.ecns.2017.09.010
38. Foronda CL, Fernandez-Burgos M, Nadeau C, et al. Virtual Simulation in Nursing Education: A Systematic Review Spanning 1996 to 2018. Simul Healthc 2020;15(1):46–54; doi: 10.1097/SIH.0000000000000411
39. Smith SJ, Farra S, Ulrich DL, et al. Learning and retention using virtual reality in a decontamination simulation. Nurs Educ Perspect 2016;37(4):210–214; doi: 10.1097/01.NEP.0000000000000035
40. Jung EY, Park DK, Lee YH, et al. Evaluation of practical exercises using an intravenous simulator incorporating virtual reality and haptics device technologies. Nurse Educ Today 2012;32(4):458–463; doi: 10.1016/j.nedt.2011.05.012
41. Smith SJ, Farra SL, Ulrich DL, et al. Effectiveness of two varying levels of virtual reality simulation. Nurs Educ Perspect 2018;39(6):E10–E15; doi: 10.1097/01.NEP.0000000000000369
42. Chang C-I. A review of virtual dimensionality for hyperspectral imagery. IEEE J Sel Top Appl Earth Observations Remote Sensing 2018;11(4):1285–1305; doi: 10.1109/JSTARS.2017.2782706
43. Checa D, Miguel-Alonso I, Bustillo A. Immersive virtual-reality computer-assembly serious game to enhance autonomous learning. Virtual Real 2021;1–18; doi: 10.1007/s10055-021-00607-1

Address correspondence to:
Samar Thabet Jallad, Assist. Prof.
Department of Nursing
Faculty of Health Professions
Al-Quds University
Palestine

E-mail: sammar1986@live.com