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Effects of Preclinical Virtual Reality Simulation in Undergraduate Nursing Students

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Effects of Preclinical Virtual Reality Simulation in Undergraduate Nursing Students

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Abstract : Virtual reality (VR) simulation in nursing education, especially in the teaching of VR simulations just prior to clinical practice, has the potential to enhance the effectiveness of clinical practice and better prepare nursing students for patient care. The aim of this study was to evaluate the effect of a preclinical VR simulation education program on the development of critical thinking, self-efficacy, problem-solving ability, and perceived clinical competency among undergraduate nursing students. The study was conducted between May and June 2021 using a pretest-posttest design with a control group. A total of 42 nursing students were recruited through convenience sampling from two separate classes. The intervention group participated in VR simulation education, while the control group engaged in lecture-based education, before beginning clinical practice. Assessments were conducted before preclinical education and after completing clinical practice using structured questionnaires. The data was analyzed using chi-square tests, independent t-tests, and ANCOVA. The findings indicated that the intervention group had a significantly higher score in perceived clinical competency compared to the control group ($F = 5.25$, $p = 0.029$) after controlling for pretest scores. However, there were no statistically significant differences in critical thinking, self-efficacy, or problem-solving abilities between the two groups. These findings suggest that preclinical VR simulation education is partially effective in preparing nursing students for their clinical practice, underscoring the need for a balanced educational approach that integrates VR with clinical practice to develop a full spectrum of nursing skills and knowledge.

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Keywords : Virtual reality simulation, perceived clinical competency, undergraduate nursing students, clinical practice, nursing education

1. Introduction

Clinical practice is a fundamental aspect of nursing education, providing a crucial bridge between theoretical knowledge and practical application. It facilitates the development of essential skills such as hands-on nursing procedures, critical problem-solving, and communication, which are vital for effective patient care and teamwork. These experiences are indispensable in preparing competent nursing practitioners [1].

However, gaining direct clinical experience has become increasingly challenging. Modern patient-centered care models and enhanced patient rights often limit the involvement of nursing students in direct patient care. The COVID-19 pandemic further exacerbated these challenges, limiting opportunities for in-person clinical education and increasing reliance on observational practices, which may not fully utilize the valuable clinical training time [2,3]. These constraints can lead to anxiety, decision-making uncertainty, and a decrease in motivation and interest among novice nursing students, adversely affecting their education and future practice [4,5]. Consequently, it is imperative to reevaluate and enhance nursing education frameworks to ensure students are adequately prepared for clinical settings [2, 6].

Virtual Reality (VR) simulation has emerged as an innovative educational tool in response to these challenges. It offers a comprehensive and interactive platform that simulates a variety of clinical scenarios, allowing students to practice procedures, decision-making, and patient management in a risk-free environment. This approach transforms potential errors into learning opportunities, rather than crises, and has been shown to improve various competencies in nursing students, such as severity classification, performance confidence, and clinical decision-making [7,8]. VR simulation provides exposure to diverse clinical situations without the consequences of real-world settings, thereby enhancing patient safety and clinical effectiveness. It can also alleviate the stress associated with initial clinical experiences, aiding students in refining their skills and self-efficacy [9,10].

Despite the recognized benefits of VR in nursing education, existing research on its effectiveness in actual clinical nursing practice is limited and preliminary. A systematic review suggested that while VR simulation was effective in improving knowledge, it was not more effective than other nursing education methods in enhancing skills or confidence [11]. Another review noted that only a few studies showed significant intervention effect for VR simulation [12]. In this context, VR can serve as a valuable complementary tool in nursing education, particularly when combined with other educational methods. Integrating VR into nursing education is important for maximizing clinical practice effectiveness and preparing students for high-quality patient care.

Focusing on VR simulation as a preclinical training method in clinical practice could bridge the gap in preparing nursing students for clinical environments. This approach could lead to more effective training methods that better align with the realities of nursing practice. Therefore, this study aimed to evaluate the effectiveness of a preclinical VR simulation education program for undergraduate nursing students, investigating its impact on critical thinking, self-efficacy, problem-solving ability, and perceived clinical competency during their first clinical practice.

The study hypotheses were as follows:

1. The intervention group that participated

in the preclinical VR simulation education program will have a higher level of critical thinking compared to the control group that participated in the preclinical lecture education program.

2. The intervention group that participated in the preclinical VR simulation education program will have a higher level of self-efficacy compared to the control group that participated in the preclinical lecture education program.

3. The intervention group that participated in the preclinical VR simulation education program will have a higher level of problem-solving ability compared to the control group that participated in the preclinical lecture education program.

4. The intervention group that participated in the preclinical VR simulation education program will have a higher level of perceived clinical competency compared to the control group that participated in the preclinical lecture education program.

2. Research method

2.1. Design and participants

An equivalent control group pretest–posttest design was employed to evaluate a preclinical VR simulation education program on nursing students embarking on their first clinical experience.

The study focused on third-year nursing students from a university located in C city, Korea, all of whom were enrolled in the Adult Nursing Practice 1 course. Participants were chosen through convenience sampling from two separate classes. The inclusion criteria required that students have no prior experience with hospital clinical practice, possess the ability to understand and effectively communicate the questionnaire content, and voluntarily agree to participate in the study. Participants were assigned to two groups based on their respective classes through a coin toss. Class A (head of the coin) constituted the intervention group, comprising 24 students divided into three teams of eight. Class B (tail of the coin) served as the control group and had the same size and organizational structure to the intervention group.

The study was designed with an anticipated effect size (ES) of 0.50 for sample size determination, influenced by a prior meta-analysis that suggested an ES of 0.56 for assessing the impact of preclinical VR simulation programs [13]. Aiming for a statistical power of 0.80 and with a significance level set at 0.05, and employing the ANCOVA methodology for analysis, the required sample size was established at 42 participants. To account for a potential dropout rate of 15%, 48 students were initially recruited to ensure adequate sample size. Of the 48 students who expressed interest and consented to participate, six were excluded from the final analysis for the following reasons: three were unable to attend the program, and three provided incomplete survey responses. Thus, the final sample size was 42 students, with 21 in each group, which satisfied the initially calculated sample size requirement as depicted in Fig. 1.

To minimize the potential of contamination effects and to maintain blinding of the study, the classes were assigned to the intervention and control groups using a coin flip. This ensured random allocation to two different hospitals and that both participants and faculty members were unaware of the group assignments, thus maintaining the experimental and control group anonymity. This step was crucial to eliminate bias and safe guard the validity of the study findings.

2.2. Study procedure

The study was conducted from May to June 2021, commencing with a pretest survey to assess their general characteristics and baseline abilities in clinical thinking, self-efficacy, problem-solving ability, and perceived clinical

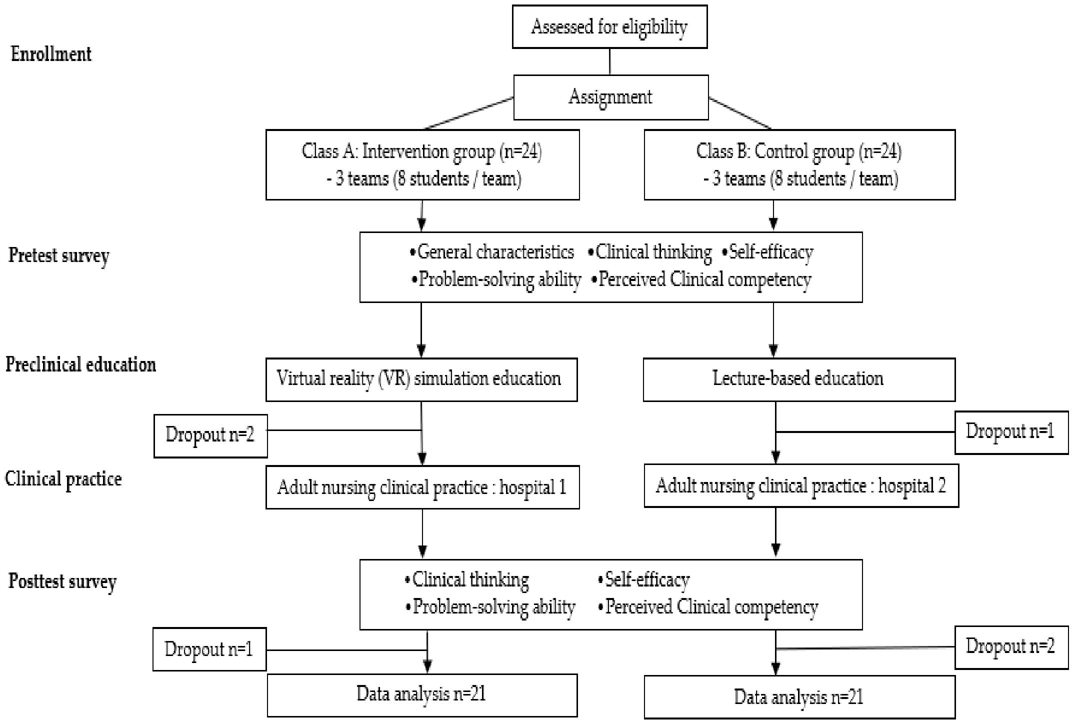

Fig. 1. Study flowchart.

competency. Both the intervention and control groups began with a one-hour orientation. The following four days comprised four one-hour preclinical education in two sessions. Subsequently, each group embarked on a two-week (10-day) clinical practice in separate hospital wards. A posttest survey followed, focusing on the educational outcomes without collecting general characteristics data.

For the intervention group, the preclinical VR simulation program began with an hour-long introduction to VR technology on the first day. This was followed by Session 1 on the second day, where students read a Chronic Obstructive Pulmonary Disease (COPD) scenario and completed a related quiz. On the third day, they engaged in a VR simulation of the COPD scenario, followed by a post-simulation quiz, with faculty providing feedback throughout. Session 2, centered on a Diabetes Mellitus (DM) scenario, was conducted on the fourth and fifth days in a similar format. In comparison, the control group's preclinical education involved an initial orientation session. Over the next four days, they attended two four-hour sessions focusing on COPD and DM. These sessions included lectures with booklets and presentation materials, supplemented by discussions and question-and-answer sessions to deepen understanding. Both groups received an equal amount of educational time and were exposed to the same topics.

The Virtual Reality (VR) simulation program used into this study was developed with the primary objective of enhancing adult nursing clinical practice for undergraduate nursing students embarking on their first clinical experience. The program focused on medical patient care, a crucial aspect of adult nursing practice. We selected advanced VR simulation software procured from Laerdal Medical and Wolters Kluwer, known for their high-quality educational tools in healthcare. The software, vSim for nursing, stands out in nursing education for its wide array of interactive, scenario-based simulations [14]. We specifically selected scenarios related to chronic obstructive pulmonary disease (COPD) and diabetes mellitus (DM) due to their relevance and importance in the adult nursing clinical practice 1 course. This immersive software allows students to engage in realistic clinical situations, thereby enhancing their critical thinking and problem-solving skills in a safe environment.

Integrating this VR simulation into the existing nursing curriculum involved several steps. Initially, three clinical practice faculty members and three clinical nursing instructors collaborated to identify essential learning outcomes aligned with the adult nursing practice module. We then selected the COPD and DM scenarios from vSim for nursing with these outcomes. To ensure program accessibility, each student was assigned a unique ID and password.

2.3. Instruments

The critical thinking disposition tool was developed by Yoon (2008) for nursing students [15] and comprises seven subcategories: prudence (four items), intellectual passion and curiosity (five items), confidence (four items), intellectual fairness (four items), systematicity (three items), sound skepticism (four items), and objectivity (three items). Each item is rated on a five-point Likert scale (1 = "very rare" and 5 = "very frequent"). The total score ranged from 27 to 135, with higher scores indicating a greater tendency toward critical thinking. The tool demonstrated good internal consistency in previous studies (Cronbach's alpha = .84) [15,16] and this study (Cronbach's alpha = .84).

Self-efficacy was assessed using the Self-Efficacy Scale, originally developed by Sherer et al. [17] and revised by Jung [18]. The scale consists of 17 items, each rated on a 5-point Likert scale, with the total possible score ranging from 17 to 85. Higher scores indicate greater levels of self-efficacy. Previous reliability analyses have yielded Cronbach's alpha values of .86 for the original scale and 94 for the Korean version [18]. In this study, the scale maintained its high internal consistency with a Cronbach's alpha of .95. The average score of all items was utilized for subsequent analyses.

Problem-solving abilities of the participants were evaluated using a Korean adaptation of a tool originally developed by Lee [19]. This tool is composed of 25 items distributed across five domains: problem discovery, problem definition, problem solution designation, problem solution application, and problem-solving process evaluation. Items are rated on a 5-point Likert scale, with total scores varying between 25 and 125. Higher scores denote superior problem-solving abilities. The tool has demonstrated strong reliability in prior research with Cronbach's alpha values of 96 [20] and was confirmed to be reliable in this study with a Cronbach's alpha of 95. The mean score for all items was calculated for analysis.

Perceived clinical competency was assessed using a questionnaire developed by Lee et al. [21] for Korean nursing students. This questionnaire includes 45 items across five domains: nursing process, nursing skills, education and cooperation, interpersonal and communication skills, and professional development. Each item is evaluated on a 5-point Likert scale, resulting in a total score range of 45 to 225. A higher score represents greater perceived clinical competency. The original questionnaire demonstrated a high internal reliability coefficient of 96, which was validated in the present study with a coefficient of .97.

2.4. Data analysis

The data were analyzed using SPSS version 27.0 (IBM Corp., Armonk, NY, USA). The level of statistical significance was set at $p < 0.05$ for all tests. To establish the pre-intervention homogeneity between the intervention and control groups, chi-square tests were used for categorical variables such as gender, GPA, and preferred education method, while independent t-tests were employed for continuous variables like age and baseline scores of critical thinking, self-efficacy, problem-solving ability, and perceived clinical competency. The effect of VR simulation education prior to clinical practice on nursing students was analyzed using ANCOVA, which adjusted for pretest scores as covariates.

2.5. Ethnical considerations

This study adhered to the ethical standards set forth in the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. The research design and procedures were reviewed and approved by the bioethics committee of the institution to which the researcher belongs (IRB No: SM-202103-016-2). Prior to the start of the study, the researcher provided a detailed explanation of the study's purpose, content, and methodology, and obtained written consent from willing participants prior to data collection. A consent form included detailed voluntary study participation, guarantee of anonymity, and scope of the use of the survey data. Participants were also informed that they were free to withdraw from the study at any time with no negative consequences. To ensure confidentiality, all collected data and personal information of the participants were encrypted and securely stored. The management of personal information was conducted in strict compliance with relevant data protection laws and guidelines.

3. Results and discussion

3.1. Participant characteristics and homogeneity test

The study comprised a total sample of 42 participants, evenly divided between the control group (n=21) and the intervention group (n=21). Table 1 presents the homogeneity tests for general characteristics and dependent variables between the control and intervention groups. The mean age of participants was 21.68 years, with a range from 20 to 26 years. Most participants in both groups were female (83.3%). Concerning the GPA, a predominant number of the students in both groups achieved a final grade between 3.5 and 4.0 in the adult nursing course (scaled to a maximum of 4.5). More than half of the participants (52.3%) expressed preference for a lecture-based education method.

In the homogeneity test of this study, no significant differences were observed be-tween the control and intervention groups in terms of general characteristics such as age, gender, GPA, and preferred educational method. Similarly, the dependent variables—critical thinking, self-efficacy, problem-solving ability, and perceived clinical competency—also showed no significant differences between the groups.

3.2. Effects of the preclinical VR simulation education program

Table 2 shows the effects of the VR simulation education before clinical practice on primary outcomes, including critical thinking, self-efficacy, problem-solving ability, and perceived clinical competency. After adjusting for pretest scores, the intervention group had a significantly higher score in perceived clinical competency compared to the control group ($F = 5.25$, $p = 0.029$). The posttest adjusted mean (SE) score for perceived clinical competency was 3.84 (0.11) for the intervention group, while it was 3.60 (0.08) for the control group.

Table 1. Homogeneity for general characteristics and outcomes between the groups

Variables	Control group (n =21)	Intervention group (n = 21)	Total (n = 42)	t / x2	*p*-value
	n (%) or M (SD)				
Age, years	21.94 (2.79)	21.41 (1.28)	21.68 (2.16)	0.71	0.483
Gender				2.11	0.146
Female	19 (90.5)	16 (76.2)	35 (83.3)		
Male	2 (9.5)	5 (23.8)	7 (16.7)		
GPA				0.78	0.854
≥ 4.0	2 (9.5)	3 (14.3)	5 (11.9)		
3.5- 〈4.0	13 (61.9)	12 (57.1)	25 (59.5)		
3.0- 〈3.5	4 (19.1)	3 (14.3)	7 (16.7)		
〈 3.0	2 (9.5)	3 (14.3)	5 (11.9)		
Preferred method of education				1.89	0.388
Lecture	10 (47.6)	12 (57.1)	22 (52.3)		
Practice	7 (33.3)	6 (28.6)	13 (31.0)		
Others	4 (19.0)	3 (14.3)	7 (16.7)		
Critical thinking	3.50 (0.21)	3.34 (0.39)	3.42 (0.32)	1.45	0.157
Self-efficacy	3.62 (0.38)	3.64 (0.69)	3.63 (0.55)	-0.07	0.943
Problem-solving ability	3.55 (0.23)	3.50 (0.65)	3.52 (0.48)	0.25	0.804
Perceived Clinical competency	3.44 (0.32)	3.42 (0.48)	3.43 (0.40)	0.14	0.892

GPA = grade point average; * M = mean; SD = standard deviation.

Table 2. Analysis of ANCOVA of dependent variables between the groups (*n* = 42)

Variables	Group	Mean (SD)	Adjusted Mean (SE)	F	*p*-value
Critical thinking				2.49	0.125
	Intervention	3.62 (0.55)	3.68 (0.13)		
	Control	3.57 (0.22)	3.50 (0.05)		
Self-efficacy				2.23	0.146
	Intervention	3.85 (0.53)	3.85 (0.13)		
	Control	3.74 (0.22)	3.74 (0.05)		
Problem-solving ability				1.02	0.320
	Intervention	3.67 (0.81)	3.69 (0.20)		
	Control	3.60 (0.30)	3.58 (0.07)		
Perceived clinical competency				5.25	0.029
	Intervention	3.83 (0.45)	3.84 (0.11))		
	Control	3.61 (0.31)	3.60 (0.08)		

SD = standard deviation; SE = standard error

However, the differences in critical thinking ($F = 2.49$, $p = 0.125$), self-efficacy ($F = 2.23$, $p = 0.146$), and problem-solving ability ($F = 1.02$, $p = 0.320$) were not statistically significant between the groups. Therefore, while VR simulation education prior to adult nursing clinical practice significantly improved perceived clinical competency, it did not have a statistically significant impact on critical thinking, self-efficacy, and problem-solving ability. As a result, hypotheses 1, 2, and 3 were rejected, while hypothesis 4 was accepted.

The present study investigated the impact of a preclinical VR simulation education program on critical thinking, self-efficacy, problem-solving ability, and perceived clinical competency among undergraduate nursing students during their initial clinical practice. The primary finding of this study was a significant improvement in perceived clinical competency among the intervention group that underwent preclinical VR simulation education, compared to the control group that received lecture-based education before clinical training. However, the study did not find significant differences in critical thinking, self-efficacy, or problem-solving ability between the preclinical VR simulation and lecture groups. These findings suggest that VR technology is partially effective in preparing students for real-world clinical experiences. Moreover, it underscores the need for a balanced approach in nursing education that integrates both traditional and innovative methods to develop a comprehensive skill set in nursing students.

In this study, the finding that there was no significant difference in the development of critical thinking skills between VR simulation training and traditional lecture-based education is consistent with previous research in the field. For example, a study comparing participants engaged in digital clinical experiences with those using written case studies found similar results, with no significant difference in critical thinking skills between the two groups [22]. Another study focused on Korean nursing students, using vSim for nursing for VR education, also reported no significant changes in critical thinking. It highlighted the importance of considering cultural and linguistic factors in VR education [23]. In current study, the VR scenarios focused on Chronic Obstructive Pulmonary Disease (COPD) and Diabetes Mellitus (DM). These scenarios, presented in English, may not have been well-aligned with typical hospital environments in Korea. The lack of alignment could have limited the students' ability to deeply engage with the VR content and effectively apply it to their local clinical contexts. These insights emphasize the need to align VR simulation content not only with educational objectives but also with the cultural and linguistic background of learners in order to enhance the effectiveness of VR in nursing education. Moreover, some students might have been more focused on navigating the VR technology itself, rather than engaging deeply with the clinical content. This initial learning curve could detract from the development of critical thinking skills.

Contrary to the second hypothesis, no significant difference in self-efficacy was observed between the two groups. This finding aligns with a previous quasi-experimental study where VR simulation-based decontamination training showed similar results [24]. The lack of difference in self-efficacy could be partially attributed to the duration and frequency of the VR intervention. In this study, participants underwent only 4 hours of VR simulation training for 4 days as a pre-training. It is possible that a longer period of exposure with repeated sessions might be necessary to achieve a noticeable improvement in self-efficacy. In contrast, another study found that nursing students who participated in VR simulation combined with neonatal nursing practice experienced significantly greater improvements in self-efficacy for high-risk neonatal infection control compared to those who only received neonatal nursing practice [25]. These mixed findings indicate the need for longitudinal studies to better understand the impact of VR simulation training on self-efficacy among nursing students, particularly in the context of high-risk or specialized clinical situations.

The intervention group, which experienced preclinical VR simulation education, did not show any significant improvement in problem-solving abilities compared to the control group. This finding is consistent with previous research indicating that virtual simulation does not significantly enhance problem-solving skills in nursing students [26]. One possible explanation for these results is that the VR scenarios used in this study had a limited scope, which may not have fully challenged and developed the students' problem-solving abilities. Real world clinical environments are typically complex and multifaceted, demanding high levels of cognitive engagement and adaptability. In contrast, the relatively narrow scenarios presented in the study might not have provided enough stimulation to develop the problem-solving abilities in the students. To better prepare nursing students for the realities of clinical practice, incorporating a wider range of complex, real-life inspired scenarios into VR simulations could be beneficial. By doing so, VR simulations could more effectively cultivate the problem-solving capabilities necessary for effective nursing practice.

The study found that the intervention group exposed to preclinical VR simulation demonstrated higher clinical competency than those receiving traditional lectures. This enhanced competency can be linked to the immersive and interactive qualities of VR. Unlike conventional teaching methods, VR provides a realistic environment where students can develop not only technical skills but also vital competencies like situational awareness and clinical judgment. The active participation in VR simulations fosters deeper learning and better retention of clinical skills [27, 28]. Furthermore, integrating reflective practices and structured debriefing sessions post-simulation has been shown to significantly boost self-assessment and self-confidence. These sessions allow learners to reflect on their performance, identify improvement areas, and internalize their experiences, thus enhancing their clinical competency [29]. These findings are supported by existing literature. A re-view of multiple studies found that VR simulations generally have a positive impact on skill acquisition and competency development [10]. A quasi-experimental study also re-ported outcomes similar to this study, indicating that VR simulation education effectively improves performance confidence and clinical decision-making skills [8].

This study, while providing valuable insights, has certain limitations that should be acknowledged. Firstly, the study was conducted at a single institution with a small sample size, utilizing convenience sampling and group assignment based on class, potentially constraining the applicability of the findings to broader educational or clinical contexts. Additionally, relying on self-reported measures introduces the possibility of social desirability bias, potentially affecting the accuracy of the results. Another limitation is the relatively short duration of the intervention, which may not have allowed for a comprehensive evaluation of the long-term impacts of the preclinical VR simulation education program. Furthermore, the initial technical proficiency of participants in VR simulation was not measured before the study began, which could have influenced the study's outcomes. Lastly, the assignment of the intervention and control groups to different hospitals' internal medicine wards introduces an additional variable. The variation in clinical environments may have influenced the effectiveness of the VR simulation education program in real clinical practice following the training period.

The findings of this study have implications for nursing education and practice. Firstly, VR simulations can enhance clinical competency and be a valuable addition to nursing curricula. VR provides a safe environment for students to practice clinical skills, preparing them for real-world situations. Secondly, to maximize the educational value of VR simulations, it is important to carefully design and implement them. This includes incorporating comprehensive and challenging scenarios, which can improve critical thinking and problem-solving skills. In nursing education, continual practice in critical thinking and problem-solving is crucial for effective decision making and providing quality nursing care [30]. Additionally, adding cultural and linguistic elements that are relevant to students' practice settings can enhance the effectiveness of the training. Thirdly, integrating VR simulations into clinical practice provides a holistic educational experience. This blended approach caters to different learning styles and addresses challenges in diverse settings. In other words, preclinical VR simulation education can improve the effectiveness of the clinical practice. Finally, ongoing research and innovation in nursing education are important to keep up with evolving healthcare technologies and practices.

4. Conclusion

This study contributes to the growing body of evidence supporting the use of VR in nursing clinical practice education, particularly in enhancing clinical competency. However, it also underscores the need for a balanced educational approach that integrates VR with clinical practice to develop a full spectrum of nursing skills and knowledge. As VR technology continues to evolve, it will be important for nursing education to adapt and optimize its use to prepare students effectively for the complexities of modern healthcare.

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