FEATURE ARTICLE

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Development and Effects of a Virtual Reality Simulation Nursing Education Program Combined With Clinical Practice Based on an Information Processing Model

Eunju Lee, PhD, RN, Gyuli Baek, PhD, RN

The need to strengthen patient human rights and create a patient-centered healthcare environment is growing. Also as science and technology develop, new educational methods using virtual reality in nursing education are emerging. This study aimed to develop a virtual reality simulation nursing education program related to postoperative patient nursing based on an information processing model and to verify its effectiveness. Clinical practice–linked virtual reality simulation nursing education was conducted for a total of 4 weeks. Nursing students were divided into an experimental group (n = 22) experiencing virtual reality simulation combined with clinical practice and a control group (n = 22) having routine clinical practice. The analytical results of this study indicated that the information processing model–based virtual reality simulation nursing education program was effective in improving nursing students' performance confidence and clinical decision-making ability. Therefore, the virtual reality simulation program developed in this study can provide basic data for the development of a simulation curriculum in the future and can contribute to the development of clinical competency as a professional nurse by improving the performance confidence and clinical decision-making ability of nursing students.

KEY WORDS: Information processing model, Learning, Nursing student, Virtual reality simulation

Author Affiliation: College of Nursing, Keimyung University (Drs Lee and Baek), Daegu, Republic of Korea.

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Gyuli Baek, ORCID: https://orcid.org/0000-0002-7915-2220

Corresponding author: Gyuli Baek, PhD, RN, College of Nursing, Keimyung University, Sindangdong, Dalseo-gu, Daegu 704-701, South Korea (koori2025@gmail.com).

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The goal of nursing students' clinical practice is to foster their ability to resolve issues including complexity, uncertainty, and conflict in the clinical field and to improve professional nursing competency and clinical decision-making by integrating theory and practice.[1,2] However, current clinical practice is limited to observation-oriented practice or simple and low-risk nursing activities due to the improvement of patient rights and lack of clinical instructors for clinical field leaders.[3,4] Such a limited clinical practicum environment reduced nursing students' ability to think critically and solve patients' actual or potential nursing problems.[5,6] Therefore, nursing students are less able to connect theory and practice and to enter hospitals without sufficiently acquiring nursing skills, which increases the time and cost of retraining new nurses in hospitals and also lowers both patient safety and quality levels of nursing service.[4]

To overcome these limitations in clinical practice, it is necessary to design a systematic clinical practice nursing education program, and in-person simulation practice education based on clinical scenarios has commenced at universities.[7] Simulation education includes Web-based virtual reality (VR) and in-person simulation education using humanlike mannequins. Currently, simulation-based practice training, which is mainly used in nursing, is conducted using high-fidelity simulators designed to produce two-way responses based on the trainee's intervention through preprogrammed physiological responses with human-sized mannequins.[8] High-fidelity simulations have the advantage of enabling interactive learning through training for learners to perform tasks and learn, promoting active participation and integrating the skills and theoretical learning necessary for practice.[9] However, this not only offers a diverse and realistic implementation of the clinical situation but also presents a limit to enhancing the proficiency of nursing skills due to insufficient repetitive training due to space use problems in the simulation room.[10]

To improve nursing students' proficiency in the implementation of professional nursing skills and improve clinical decision-making, students should organize, classify, and refine the learning acquired with sensory registers to help them be stored as long-term memories.[11] The information processing model is an approach to understanding complex human memory phenomena by comparing them with the information processing process of computers, introducing the concepts of attention, perception, automation, chunking, double-signing, organization, refinement, imaging, and contextualization.[12] This model clearly explains how the information processing of memory and learning takes place in the brain; thus, it is worth using educationally.[13,14] Information stored in short-term memory begins to be forgotten 10 minutes after learning, and more than 70% is forgotten after 24 hours. Thus, to maintain the effect of learning by preserving short-term memories as long-term memories, a cognitive learning process is necessary that can correct erroneous cognition and periodically provide repeat learning.[11,15] From this perspective, in the case of in-school simulation education, it is difficult to reorganize the learned content and store it as long-term memory because repeated practice on vulnerable individuals is limited in time and space.[11,16] Therefore, clarifying nursing problems and solving them by linking patient situations observed in clinical practicum settings with theory should be accompanied by interaction and repeated learning through feedback on cognitive errors in situations similar to actual clinical practice, resulting in effective learning.

Virtual reality is a technology that allows users who have received artificial sensory stimulation to have the same experience as real life without directly experiencing the environment or situation. Web-based VR simulation education provides realistic education similar to real situations online with only a computer, increasing the level of immersion in training and enabling repeated learning.[17–19] Recently, VR simulations have used head mounted displays and PC-based simulations that can observe 360-degree clinical sites through the left and right movement of the screen cursor or mobile device. In particular, in the case of VR implemented with head mounted displays, it is difficult to use it for more than 4 minutes due to problems such as cybersickness, so implementing a complex clinical environment using a PC-based Web program is more effective using current technology.[20,21] Although Web-based VR simulations provide immersion through patient cases similar to clinical situations, this simulation method is insufficient to master the technical aspects of nursing that must be learned by direct action practice.[22] Therefore, an efficient practical education strategy for nursing students requires clinical practice as well as Web-based VR simulation for cognitive enhancement and high-fidelity simulation to improve nursing skills.

Therefore, this study aimed to examine the effect of nursing students' clinical decision-making ability by developing and applying a nursing education program that combines Web-based VR simulation and high-fidelity simulation after practicing in a surgical ward to teach nursing care for postoperative patients. Postoperative patient care is applied in this program because the number of surgical patients is increasing based on tertiary hospitals today due to longer life expectancies and the development of medical technology.[23–25] In addition, postoperative patient care requires close professional care due to the complex nursing problems such as postoperative infection, bleeding, pulmonary complications, and pain; therefore, students need to systematically learn postoperative patient care from undergraduate education.[14,24,25] Postoperative patient nursing is presented as a nursing topic suitable for integrating the basic knowledge and skills of nursing students at the undergraduate level; thus, it is considered appropriate for the development of a simulation nursing education program linked to clinical practice. However, postoperative nursing education programs are insufficient; in particular, studies aimed at long-term memory by applying an information processing model have not been conducted. Therefore, based on the information processing model, this study develops a nursing education program that combines Web-based VR and high-fidelity simulation linked to clinical practice, and a nursing education program was applied to improve clinical decision-making ability related to postoperative patient nursing. This study is intended to provide basic data for more effective education to strengthen clinical decision-making ability in postoperative patient care.

PURPOSE

This study aimed to develop a VR simulation nursing education program related to postoperative patient nursing based on an information processing model and to verify its effectiveness.

METHODS

Design

A clinical, practice-linked, VR simulation nursing education program was applied using an information processing model, and a quasi-experimental design study was conducted using a nonequivalence control group to develop and verify its effectiveness (Supplemental Figure 1, http://links.lww.com/CIN/A281).

Participants

The study participants were students in the second semester of their third year at the nursing department of a 4-year college in Daegu, South Korea, who understood the purpose of the study and agreed to participate. The sufficient sample size was calculated as 34 (17 per group) using G*Power 3.1 (Heinrich Heine University, Dusseldorf, Germany) based on a previous study[26] that showed significant research results with repeated measures analysis of variance for nursing students with a medium effect size of 0.25, 80% power, and a significance level of .5. Considering the dropout rate and poor response, 44 participants in the intervention group and control group were recruited as targets.

Measures

Confidence in Performance

To measure the effectiveness of simulation education for nursing students, researchers used an instrument developed by

Kim,[27] comprising 10 items, including assessment (four items), diagnosis (two items), intervention (three items), and evaluation (one item). This instrument uses a 5-point Likert scale rating system, ranging from 1 (not at all) to 5 (very likely); the higher the score, the higher the confidence. Cronbach's α was calculated to be .80 in Kim's study[27] and .90 in this study.

Clinical Decision-Making Ability

Clinical decision-making ability was measured using the Clinical Decision Making in Nursing Scale developed by Jenkins[28] and translated and modified by Back.[29] It consists of 40 items categorized into four groups: search for alternatives or options, search for information and harmonization with new information, canvassing of objective and values, and evaluation and reevaluation of consequences. Each item was rated on a 5-point Likert scale, with a higher score indicating a higher level of decision-making ability. In Back's[29] study, Cronbach's α was calculated to be .77 and was .82 in this study.

Class Evaluation

Class evaluation was measured using a lecture evaluation instrument for each class type developed by Ko et al[30] and revised by Yoo[31] according to the simulation. It consists of 12 items related to class operation, teaching methods and materials, the objectivity of evaluation, and class satisfaction. Items are scored on a 5-point Likert scale, with higher scores indicating higher class evaluations. Cronbach's α was .89 in Yoo's[31] study and .91 in this study.

Simulation Design Evaluation

To evaluate the simulation design, this study used the Simulation Design Scale, which was developed by the National League for Nursing and revised by Yoo.[31] It comprises 21 items, including learning goals and education (six items), support (four items), problem-solving (five items), feedback (four items), and realism (two items). Items are scored on a 5-point Likert scale, with higher scores indicating a better simulation design. Cronbach's α was .90 in Yoo's[31] study and .96 in this study.

Practice Flow

Practice flow was measured with the flow measurement instrument developed by Engeser and Rheinberg[32] and revised by Yoo.[31] It consists of 10 items, namely, proficiency in performance (six items) and immersion in action (four items), using a 5-point Likert scale. The higher the score, the more immersive the practice. Cronbach's α was .84 in Yoo's[31] study and .91 in this study.

Data Collection and Ethical Considerations

This study was approved by the institutional review board of the researcher's affiliated university (no. 40525-202107-HR-051-01). Data were collected from September 7 to November 28, 2021, with 22 third-year nursing students as the experimental group and 22 students as the control group. Prior to data collection, participants were informed about the research purpose, methods, process, and their rights in detail. Students who volunteered to participate in the research were allocated sequentially to the experimental and control groups. The experiment was conducted such that the participants did not know their group. Data collection was conducted four times a week for 2 hours, and all participants who completed data collection received a gift.

Development of the Program

In this study, a nursing education program for strengthening clinical decision-making ability using VR was developed using the Analysis, Design, Development, Implementation, and Evaluation model (Table 1; Supplemental Figure 2, http://links.lww.com/CIN/A282).

First, the learning needs of third-year students who took adult nursing and had practical clinical experience were identified in the analysis stage through a survey, and an efficient method for strengthening clinical decision-making ability was reviewed through a literature analysis and the learning goals of the Korean Nursing Association. The nursing college curriculum was checked to evaluate course completion and the timing of clinical practice. The structure, arrangement, and learning availability of the simulation classroom were confirmed through a field survey.

Second, in the design stage, the learning goals were reviewed, and the learning outcomes of the Korea Nursing Education and Assessment Service were reflected. The learning content was set as postoperative patient nursing, including vital sign measurement, intravenous patient controlled analgesia management, chest tube management, pulse oximeter measurement, electrocardiogram monitoring, oxygen therapy with a nasal cannula, and intramuscular injection. For the learning operation method, a clinical practice–linked VR simulation nursing education program based on an information processing model was implemented. In the preparation stage of clinical practice for the transition from sensory to short-term memory, patient nursing theory video lectures, patient nursing demonstrations, patient's chief complaint identification before rounding, prior perception of the patient's chief complaint, and patient-related clinical questions were derived in an attention and perception process. Next, the short-term memory step was repeated, and feedback was provided through a double-signing process that connects theoretical and visual data related to nursing diagnosis and through chunking, which forms meaningful data units through patient data collection in the clinical practice stage. In the transition stage from short-term to long-term memory, Web-based VR simulation and high-fidelity simulation were combined and applied. In

Table 1. Program Development Process

Developing Nursing Education Program for Strengthening Clinical Decision-Making Ability Using VR	
Preparation	
Analysis	1. Literature review 2. Survey of students' educational needs 3. Program development design analysis 4. Selection of measurement instruments
Design	1. Form a development team with expertise and practical experience 2. Selection of simulation topics 3. Simulation curriculum design 4. Selection of scenario case 5. Selection of key problems and nursing skills in the scenario 6. 3D movie continuity production 7. Web page construction for Web-based VR implementation
Development	1. Video lecture production on patient nursing theory 2. Simulation scenario development 3. Building a simulation environment 4. Production of theoretical and visual data related to nursing diagnosis 5. Web-based VR simulation prequiz and postquiz development 6. 3D movies shooting and editing 7. Uploading a Web-based VR program to a Web page
Implementation	
Session 1: clinical practice	1. Attention concentration through video lectures on patient nursing theory 2. Patient nursing demonstration 3. Check the order before patient rounding 4. Perception of patient ordering dictionary content 5. Derive patient-related clinical questions 6. Form meaningful data units through patient data collection 7. Talk about nursing diagnosis applicable to relay game format 8. Connecting the theory and visual data on nursing diagnosis
Session 2: Web-based VR simulation	1. Identification of patient cases and organization through inferring nursing problems 2. Elaboration through the application of nursing process 3. Nursing diagnosis and nursing performance selection 4. Present the situation with a 3D video 5. Imaging through the provision of hints based on pictures and videos
Session 3: high-fidelity simulation	1. Connecting Web-based VR simulation and high-fidelity simulation context 2. Patient identification and assessment 3. Direct practice of nursing skill performance 4. Therapeutic communication 5. Provide debriefing
Evaluation	
	Confidence in performance Clinical decision-making ability Practice flow Class evaluation Simulation design evaluation

Abbreviation: 3D, three-dimensional.

the transition stage from short-term to long-term memory, Web-based VR simulation provides identification of VR patient cases, organization through inferring nursing problems, refinement through knowledge and skill selection in nursing situations according to the correct order, presentation of situations through a 360-degree video, and feedback, as well as presenting a pop-up window based on pictures and videos for the right choice can be made before proceeding to the next step. Finally, through high-fidelity simulations, significance is provided by linking the previous clinical practice and VR simulations and a scenario discussion of team learning, based on the clinical situation scenario of surgical patient nursing, providing contextualization for learners to recognize problems and have direction in the problem-solving process in nursing plans and interventions.

Third, to develop learning materials and confirm their suitability in the development stage, content validity was verified by visiting experts, consisting of two adult nursing professors and three clinical nurses with more than 5 years of clinical experience in surgical patient nursing. Five third-year students from universities that the participants did not attend were selected. The program was applied on a trial basis and then revised and supplemented to develop the final Web-based VR simulation program.

Fourth, a Web-based VR simulation program was installed on the Web page developed by the researcher of this study. After URLs were distributed to learners, learners could access them through individual computers, mobile devices, tablets, and so forth. In the system's interface, the researcher individually transmitted the access URL to the students after generating an ID using the student's school number in administrator mode. All curricula were conducted sequentially. Only when the correct answer to the quiz in the middle of the program was given did the program move to the next step. For effective education, fast-forwarding and skipping were not allowed. After the program was implemented, postquiz scores, as well as indications of whether hints for quizzes that appeared in the middle of the program were read, can all be checked on the administrator page, and the final score can be checked and downloaded in Excel. Hence, an objective evaluation based on these scores was possible.

Application of the Program

The intervention application process in this study was conducted according to the procedure shown in Supplemental Figure 2, http://links.lww.com/CIN/A282.

Preliminary Investigation

Before conducting the education program, online questionnaires were used to survey participants' age, preferred education method, grades in the previous semester, general characteristics and performance confidence, and clinical decision-making ability.

Application

Clinical practice–linked VR simulation nursing education was conducted for 4 weeks. During week 1, a clinical practice preparation stage was undertaken, composed of 2 hours of prelearning, including watching patient theory videos and acquiring sensory memory, and 1 hour of patient nursing demonstration, including understanding the patient's chief complaint before rounding, prior perception of patient's chief complaint, and eliciting patient-related clinical questions. After 2 weeks of clinical practice, the experimental group freely conducted Web-based VR simulation training at the time and place they chose for 2 hours in the fourth week, and they were encouraged to self-review for 2 hours after the program. The Web-based VR simulation education was conducted using video lectures, prequizzes, Web-based VR simulations, and postquizzes after surgery by applying an information processing model. The learner accessed the Web page through an individual ID and password to take a prevideo lecture and a five-question prequiz. If the prequiz score was less than 80 points, repetitive learning was performed; if the score was more than 80 points, the Web-based VR simulation was started. A quiz is presented during the process of performing the nursing intervention in a postoperative patient nursing situation, and related concepts and clues to the quiz are presented using 360-degree videos and pictures. After the program is completed, the entire Web-based VR simulation education program was terminated if the five postquiz scores exceeded 80 points. Feedback was provided through a pop-up window, and feedback from nursing records was provided by high-fidelity simulation deprivation. On the last day of the fourth week, performance-based high-fidelity simulation and deprivation were conducted for 4 hours at the school simulation center. The training consisted of orientation and scenario discussion, core nursing skills training, simulation driving, and debriefing. Debriefing is intended to allow instructors and learners to share feelings about the nursing care performed after practicums. This study evaluated videos recorded for debriefing using the Gather-Analysis-Summarize model.[33] The Gather step is to determine the learner's reaction after simulation activities, in other words, to listen to the learner's thoughts and feelings about the nursing performance. The Analysis step analyzes the performance, and the Summarize step reviews what has been learned through simulation education. Given the recommendation that the debriefing time should be two to four times the simulation practice time and proceed over 30 minutes,[34] this study had a debriefing time of 60 minutes.

In the control group, to which the existing high-fidelity simulation was applied, 2 hours of prelearning were performed in the first week of the clinical practice preparation stage. After 2 weeks of clinical practice, high-fidelity simulation and debriefing were conducted for 4 hours in the same scenario as the experimental group on the last day of the fourth week.

Follow-up Investigation

After training, the two groups were surveyed for performer confidence, clinical decision-making ability, clinical practice immersion, class evaluation, and simulation design evaluation using an questionnaire.

Data Analysis

The data collected in this study were analyzed using IBM SPSS Statistics version 27 (IBM Inc., Armonk, NY, USA). The general characteristics of the subjects were analyzed using real numbers, percentages, means, and standard deviations, and a homogeneity test of the general characteristics of the subjects was analyzed using the χ^2 and Fisher's exact tests. The homogeneity of the performer's confidence and clinical decision-making ability was analyzed using an independent t

test. Repeated measures analysis of variance was used to analyze the effectiveness of the performers' confidence and clinical decision-making ability before and after the program in the two groups. The differences between the two groups' posteducation class evaluation, simulation design evaluation, and clinical practice immersion were analyzed using an independent t test, and the reliability of the instrument was verified using Cronbach's α.

RESULTS

The general characteristics and homogeneity of the study participants are shown in Table 2. Of the 44 participants, 22 each were placed in the experimental and control groups, with a mean age of 21.13 years in the experimental group and 21.30 years in the control group. Regarding preferred education method, participants indicated performance as 9 (43.5%), whereas in the control group, lecture was 10 (55%). Regarding the last semester grade, 16 (73.9%) of the experimental groups and 13 (60.9%) of the control group scored 3.5 or more and less than 4.0, respectively. There was no significant difference in age, preferred education, and last semester grades between the two groups in terms of the homogeneity of general characteristics ($P > .05$). In addition, no significant difference between the groups was observed in confidence in performance ($t = -0.87$, $P = .097$) and clinical decision-making ability ($t = -1.87$, $P = .167$), based on the results of the homogeneity of dependent variables in the two groups.

Pretest-posttest mean differences in confidence in performance and clinical decision-making ability between the experimental and control groups are shown in Table 3. Regarding posttest confidence in performance, the experimental group score was an average of 4.36 (±0.23), higher than that in the control group (4.00 [±0.35]), and showed statistically significant differences in the interaction between group and time. Regarding the various categories of confidence in performance, statistically significant differences were seen in the assessment ($F = 10.42$, $P = .002$), intervention ($F = 5.63$, $P = .022$), and evaluation ($F = 6.76$, $P = .013$) stages. Regarding the posttest clinical decision-making ability, statistically significant differences were found between the experimental group 3.60 (±0.24) and the control group (3.56 [±0.30]) ($F = 7.26$, $P = .010$). Regarding the subfactors of clinical decision-making ability, differences in the interaction between group and time were statistically significant in "search for alternatives or options" ($F = 9.11$, $P = .004$) and "canvassing of objective and values" ($F = 9.10$, $P = .003$).

The posttest mean differences in class evaluation, simulation design evaluation, and practice flow between the experimental and control groups are shown in Table 4. In the posttest class evaluation, the experimental group's mean score of 4.71 (±0.28) was higher than that of the control group (4.37 [±0.30]), showing statistically significant mean differences ($t = 3.85$, $P < .001$). The mean of the experimental group was 4.48 (±0.39) in the posttest simulation design evaluation, which was higher than that of the control group (4.25 [±0.47]), but the difference was not statistically significant ($t = 1.80$, $P = .078$). In the simulation design evaluation categories, the findings revealed a statistically significant difference in feedback ($t = 2.20$, $P = .033$) and realism ($t = 3.78$, $P < .001$). There were statistically significant differences in the posttest with an experimental group mean score of 4.19 (±0.42), higher than that of the control group (3.90 [±0.52]) ($t = 2.07$, $P = .044$).

DISCUSSION

This study's clinical practice–linked VR simulation nursing education program based on the information processing

Table 2. General Characteristics and Homogeneity of the Participants (N = 44)

Characteristics	Categories	Exp (n = 22)	Cont (n = 22)	χ^2 or F	P
		n (%) or Mean ± SD	n (%) or Mean ± SD		
Age, y		21.13 ± 1.01	21.30 ± 0.87	3.53	.472
Preferred education	Lecture	7 (30.4)	10 (55.0)	3.14	.216
	Discussion	1 (4.3)	2 (8.7)		
	Q & A	5 (21.7)	9 (39.1)		
	Performance	9 (43.5)	5 (21.7)		
Last semester grade	3.0–3.5	5 (21.7)	5 (21.7)	2.09	.352
	3.5–4.0	16 (73.9)	13 (60.9)		
	4.0–4.5	1 (4.3)	4 (17.4)		

Variables	Exp (n = 22)	Cont (n = 22)	t	p
	Mean ± SD	Mean ± SD		
Confidence in performance	3.79 ± 0.35	3.91 ± 0.57	−0.87	.097
Clinical decision-making ability	3.37 ± 0.17	3.48 ± 0.23	−1.87	.167

Abbreviation: Cont, control; Exp, experimental; Q & A, question & answer.

Table 3. Pretest-Posttest Mean Differences of Confidence in Performance and Clinical Decision-Making Ability Between the Experimental and Control Groups Over Time (N = 44)

Effect Variables	Exp (n = 22) Mean ± SD	Cont (n = 22) Mean ± SD	Source	*F*	*P*
Confidence in performance					
Pretest	3.79 ± 0.35	3.92 ± 0.57	Group	2.19	.146
Posttest	4.36 ± 0.23	4.00 ± 0.35	Time	14.44	<.001
			Group/time	8.50	.006
Assessment					
Pretest	3.94 ± 0.47	4.11 ± 0.64	Group	0.82	.368
Posttest	4.41 ± 0.30	4.04 ± 0.35	Time	5.40	.025
			Group/time	10.42	.002
Diagnosis					
Pretest	3.89 ± 0.39	3.86 ± 0.58	Group	0.78	.382
Posttest	4.21 ± 0.42	4.06 ± 0.54	Time	5.81	.020
			Group/time	0.36	.550
Intervention					
Pretest	3.65 ± 0.45	3.78 ± 0.61	Group	2.82	.100
Posttest	4.36 ± 0.41	3.92 ± 0.52	Time	12.89	.001
			Group/time	5.63	.022
Evaluation					
Pretest	3.43 ± 0.66	3.06 ± 0.83	Group	1.98	.165
Posttest	4.39 ± 0.49	3.82 ± 0.65	Time	17.06	<.001
			Group/time	6.76	.013
Clinical decision-making ability: total					
Pretest	3.37 ± 0.17	3.48 ± 0.23	Group	0.33	.570
Posttest	3.60 ± 0.24	3.56 ± 0.30	Time	28.01	<.001
			Group/time	7.26	.010
Search for alternatives or options					
Pretest	3.35 ± 0.31	3.51 ± 0.32	Group	0.01	.909
Posttest	3.75 ± 0.39	3.61 ± 0.39	Time	25.30	<.001
			Group/time	9.11	.004
Search for information					
Pretest	3.57 ± 0.32	3.74 ± 0.36	Group	1.47	.232
Posttest	3.76 ± 0.42	3.85 ± 0.53	Time	6.72	.013
			Group/time	0.51	.479
Canvassing of objective and values					
Pretest	3.25 ± 0.25	3.44 ± 0.35	Group	0.81	.373
Posttest	3.45 ± 0.25	3.40 ± 0.29	Time	3.65	.062
			Group/time	9.10	.003
Evaluation and reevaluation of consequences					
Pretest	3.30 ± 0.21	3.22 ± 0.23	Group	0.89	.348
Posttest	3.40 ± 0.32	3.35 ± 0.31	Time	6.44	.015
			Group/time	0.05	.818

Abbreviation: Cont, control; Exp, experimental.

model was conducted based on the Analysis, Design, Development, Implementation, and Evaluation teaching design model, with postoperative patient care as the subject, and it attempted to provide basic data for the development and operation of clinical decision-making to strengthen nursing education.

In this study, an information and communication model was applied to describe a series of processes that transformed learning in a systematic nursing education program from sensory memory to short-term and long-term memory.[13,14,35] This study activated sensory memory through preclinical learning in the clinical practice preparation stage and

Table 4. Mean Differences of Class Evaluation, Simulation Design Evaluation, and Practice Flow Between the Experimental and Control Groups (N = 44)

Variables	Exp (n = 22) Mean ± SD	Cont (n = 22) Mean ± SD	t	P
Class evaluation	4.71 ± 0.28	4.37 ± 0.30	3.85	<.001
Simulation design evaluation				
Learning goals and education	4.42 ± 0.49	4.15 ± 0.64	1.58	.121
Support	4.38 ± 0.49	4.33 ± 0.60	0.26	.792
Problem-solving	4.33 ± 0.55	4.27 ± 0.67	0.33	.738
Feedback	4.82 ± 0.37	4.43 ± 0.76	2.20	.033
Realism	4.58 ± 0.46	3.97 ± 0.61	3.78	<.001
Total	4.48 ± 0.39	4.25 ± 0.47	1.80	.078
Practice flow	4.19 ± 0.42	3.90 ± 0.52	2.07	.044

Abbreviation: Cont, control; Exp, experimental.

strengthened short-term memory by repeating and feedbacking the process of matching abnormal patient information with nursing diagnoses in the clinical practice stage. Finally, long-term memory was targeted using a contextualization strategy, connecting high-fidelity simulation and Web-based VR simulation. Among the long-term memory strategies, the contextualization strategies presented in the information and communication model helped students learn postoperative patient care by repeating the clinical judgment process in high-fidelity simulation practice and performing nursing skills directly.[11,35]

In the design evaluation of "feedback" and "reality," the score was higher than that of the control group. This is thought to be the result of utilizing three-dimensional VR as an interaction strategy to maximize immersion and cognitive reinforcement, and provide questions and immediate feedback on clinical decision-making.[7,36] Clinical decision-making–related questions contribute to enhancing clinical decision-making by organizing patient nursing problems and using an elaborated strategy that links correct nursing planning and implementation to address them.[36]

The clinical practice–linked VR simulation program based on the information processing model was effective in improving the confidence of the performers in "assessment," "intervention," and "evaluation." The results of this study are difficult to compare directly because no studies have measured the effectiveness of nursing education based on an information processing model. However, in a study applying the information processing model to vocational education, the results were similar to previous studies showing improved confidence, academic achievement, and learning motivation in college students.[20,37] Moreover, the results of the three-dimensional simulation education for nursing students' problem-solving confidence[38] and the systematic literature review on the effectiveness of nursing education using Web-based VR on student knowledge, implementation ability, and confidence support the results of this study.[39,40] The information processing model can improve confidence and learning efficacy by reducing students' cognitive and psychological burdens through various strategies that promote the storage of learning memories.[20,37] To that end, this study used an automation process based on repetition and feedback in the clinical practice stage, instant feedback through quizzes and hints in the form of pictures and videos in the Web-based VR, and a contextualization strategy of high-fidelity simulation.[26,37] Specifically, corrective feedback has a positive effect on improving self-efficacy and performance confidence by overcoming fear of failure and promoting interest and motivation.[26,41] Therefore, this study program's immediate feedback and repetitive learning had a positive effect on improving the implementation confidence of nursing students.

Moreover, students' clinical decision-making ability was improved in the "investigation on alternatives and choices" and "review items on values and goals" segments. In order to cultivate clinical decision-making ability, it is necessary not only to memorize theoretical knowledge and skills but also to repeat learning to find nursing problems by applying existing knowledge and concepts according to the situation.[42] Clinical decision-making ability is a factor that affects the quality of nursing and develops based on knowledge, thinking process, and experience.[43] In this study, learning basic knowledge through information and communication theory-based attention and perception strategies in the preclinical practice stage, experiencing critical thinking processes to derive nursing problems in patient situations, and providing repeated experiences through simulation learning seem to have contributed to clinical decision-making. Thus, using a clinical practice–linked VR and simulation learning program based on the information processing model to improve clinical decision-making ability at clinical sites can help establish nursing strategies to solve problems in various clinical situations.

This study's clinical practice–linked, VR simulation nursing education program based on the information processing model was effective in improving class evaluation and practice immersion. Teaching and learning design applying the information processing model reduces learners' cognitive burden and contributes to academic achievement, learning motivation, and efficacy by promoting memory activation.[14] In nurse education, applying the information processing model activated the learning process in which nurses themselves infer and organize answers to clinical problems, having a positive effect on their learning attitudes and satisfaction.[44] Therefore, memory reinforcement strategies, such as organization and refinement, were actively used when conducting simulations in this study to switch from short-term memory of clinical practice to long-term memory. In addition, in the VR simulation stage, a key strategy for long-term memory, three-dimensional images captured at actual clinical sites were displayed. Therefore, promoting immersion in nursing education programs can internalize the knowledge that nursing students have acquired,[39,40] and strategies to enhance immersion are important for improving clinical decision-making and acquiring professional nursing skills.

It was found that the information processing model–based VR simulation nursing education program was effective in improving nursing students' performance confidence and clinical decision-making ability. The significance of this study is as follows. First, the study can be used as basic data for the development of educational programs to maximize the immersion and cognitive enhancement of education and improve the quality of current clinical practice–linked simulation education when limited clinical practice is being implemented in nursing research. Second, regarding nursing education, it is expected that a clinical practice–linked Web-based VR and high-fidelity simulation program, structured according to the memory reinforcement strategies of the information processing model, can be used as a new learning method to strengthen nursing students' cognitive function.

The limitations of this study are as follows. First, the generalizability of the results is limited due to the study population of nursing students at a nursing university. Second, there is a limitation in evaluating the persistence of the effect of the information processing model on long-term memory because reexamination after intervention was not conducted as a measurement parameter before and after intervention.

CONCLUSION

Study findings confirmed that the clinical practice–linked VR simulation nursing education program based on the information processing model improves nursing students' confidence in performing postoperative patient nursing and clinical decision-making ability. Therefore, the VR simulation program developed in this study can provide preliminary data for the development of a simulation curriculum in the future and can contribute to the development of clinical competency as a professional nurse by improving the performance confidence and clinical decision-making ability of nursing students.

On the basis of this study, we make the following suggestions. First, a long-term longitudinal study that can reevaluate the impact after intervention is needed to understand the continuity of the effectiveness of the program model. Second, in addition to continuous research on the development and application of scenarios based on various clinical situations and nursing techniques, it is necessary to construct an extended program to objectively evaluate the effectiveness of education by providing opportunities for repetitive practice.

References

1. Kang JY. Simulated nursing practice education in the contact age: a mixed methods case study. *Journal of Learner-Centered Curriculum and Instruction*. 2020;20(18): 937–957. doi:10.22251/jlcci.2020.20.18.937.
2. Farčić N, Barać I, Lovrić R, Pačarić S, Gvozdanović Z, Ilakovac V. The influence of self-concept on clinical decision-making in nurses and nursing students: a cross-sectional study. *International Journal of Environmental Research and Public Health*. 2020;17(9): 3059. doi:10.3390/ijerph17093059.
3. Ulenaers D, Grosemans J, Schrooten W, Bergs J. Clinical placement experience of nursing students during the COVID-19 pandemic: a cross-sectional study. *Nurse Education Today*. 2021;99: 104746. doi:10.1016/j.nedt.2021.104746.
4. Han SY, Kwak SJ, Choi BG, Jeon HJ, Lee MK. Association of nursing activity participation and clinical practice stress with career maturity during clinical practice of nursing college students. *The Journal of Korean Academic Society of Nursing Education*. 2020;26(4): 337–347. doi:10.5977/jkasne.2020.26.4.337.
5. Suh YJ, Han EK. Effects of communication competency, self-efficacy for group work, and learning transfer motivation of nursing students in psychiatric and mental health nursing practice education based on blended learning. *Journal of Industrial Convergence*. 2022;20(2): 61–70. doi:10.22678/JIC.2022.20.2.061.
6. Im KJ, Yang BS, Kim YL. Development and effects of simulation educational program for nursing students. *Journal of Digital Convergence*. 2018;16(2): 203–213. doi:10.14400/JDC.2018.16.2.203.
7. Ramos-Morcillo AJ, Leal-Costa C, Moral-García JE, Ruzafa-Martínez M. Experiences of nursing students during the abrupt change from face-to-face to e-learning education during the first month of confinement due to COVID-19 in Spain. *International Journal of Environmental Research and Public Health*. 2020;17(15): 5519. doi:10.3390/ijerph17155519.
8. Klenke-Borgmann L. High-fidelity simulation in the classroom for clinical judgment development in third-year baccalaureate nursing students. *Nursing Education Perspectives*. 2020;41(3): 185–186. doi:10.1097/01.NEP.0000000000000457.
9. Chu MS, Hwang YY. Effects of web-based simulation and high-fidelity simulation of acute heart disease patient care. *The Journal of Korean Academic Society of Nursing Education*. 2017;23(1): 95–107. doi:10.5977/jkasne.2017.23.1.95.
10. Kim MK, Kim SH, Lee WS. Effects of a virtual reality simulation and a blended simulation of care for pediatric patient with asthma. *Child Health Nursing Research*. 2019;25(4): 496–506. doi:10.4094/chnr.2019.25.4.496.
11. Kim SY. Psychiatric and mental health nursing based nursing students' coordination function brain neural network design: from a brain science

perspective. *Journal of Learner-Centered Curriculum and Instruction*. 2022; 22(10): 755–774. doi:10.22251/jlcci.2022.22.10.755.

12. Atkinson RC, Shiffrin RM. Human memory: a proposed system and its control processes. *Psychology of Learning and Motivation*. 1968;2: 89–195. doi:10.1017/cbo9781316422250.025.
13. Kim YS. Interpretation of social studies instructional models based upon the information processing metaphor. *The Journal of Learner-Centered Curriculum and Instruction*. 2014;14: 167–187.
14. Oh DY. Analysis of the effectiveness of the internet-lecture learning method based on the theory of information processing: focusing on college students' learning strategies and class participation. *Journal of Learner-Centered Curriculum and Instruction*. 2021;21(6): 761–772. doi:10.22251/jlcci.2021.21.6.761.
15. Jung JS, Hur HK. Effectiveness and retention of repeated simulation-based basic life support training for nursing students. *Journal of Korean Critical Care Nursing*. 2013;6(2): 24–36.
16. Orique SB, Phillips LJ. The effectiveness of simulation on recognizing and managing clinical deterioration: meta-analyses. *Western Journal of Nursing Research*. 2018;40(4): 582–609. doi:10.1177/0193945917697224.
17. You HE, Yang BS. The effects of virtual reality simulation scenario application on clinical competency, problem solving ability and nursing performance confidence. *Journal of the Korea Academia-Industrial*. 2021;22(9): 116–126. doi:10.5762/KAIS.2021.22.9.116.
18. Erlinger LR, Bartlett A, Perez A. High-fidelity mannequin simulation versus virtual simulation for recognition of critical events by student registered nurse anesthetists. *AANA Journal*. 2019;87(2): 105–110.
19. Lim JH. The effect of virtual reality simulation education on nursing process competency. *Journal of Digital Convergence*. 2021;19(9): 401–409. doi:10.14400/JDC.2021.19.9.401.
20. Aebersold M, Tschannen D. Simulation in nursing practice: the impact on patient care. *Online Journal of Issues in Nursing*. 2018;18(2): 6.
21. Lim SH. Content analysis on online non-face-to-face adult nursing practice experienced by graduating nursing students in the contact era. *Journal of the Korea Academia-Industrial cooperation Society*. 2021;22(4): 195–205. doi:10.5762/KAIS.2021.22.4.195.
22. Chen FQ, Leng YF, Ge JF, et al. Effectiveness of virtual reality in nursing education: meta-analysis. *Journal of Medical Internet Research*. 2020;22(9): e18290. doi:10.2196/18290.
23. Kim SS. Association rules of comorbidities in patients hospitalized for lung cancer. *Journal of Health Informatics and Statistics*. 2021;46(1): 100–109. doi:10.21032/jhis.2021.46.1.100.
24. Mekdad AK. The effect of nursing intervention on the reduction of pulmonary complications after thoracotomy. *Helwan International Journal for Nursing Research and Practice*. 2022;1(1): 152–166.
25. Jung YM, Ko YJ. Effects of simulation-based preoperative and postoperative care nursing program on problem solving ability, critical thinking disposition, and academic self-efficacy of nursing students. *Journal of Learner-Centered Curriculum and Instruction*. 2017;9: 149–168. doi:10.22251/jlcci.2017.17.9.149.
26. Lee EJ, Ryu MJ. Development and effects of a nursing education program using virtual reality for enhancing clinical decision-making ability in respiratory disease nursing care. *Journal of Korean Academy of Fundamentals of Nursing*. 2021;28(4): 458–469. doi:10.7739/jkafn.2021.28.4.458.
27. Kim HK. *Application Effect of Simulation Education for Clinical Decision Making Enhancement of Nursing Students* [dissertation]. Gwangju, South Korea: Chonnam National University; 2015:22–27.
28. Jenkins HM. Improving clinical decision making in nursing. *Journal of Nursing Education*. 1985;24(6): 242–243. doi:10.3928/0148-4834-19850601-07.
29. Back MK. *Relationship Between Level of Autonomy and Clinical Decision-Making in Nursing Scale of E.T Nurse* [master's thesis]. Seoul, South Korea: Graduate School of Public Health Yonsei University; 2004: 21–24.
30. Ko EM, Lee HK, Han EO. A study for development of the course evaluation tool for college lecture types. *The Journal of Humanities*. 2013;31(1): 365–394.
31. Yoo JH. *Factors Influencing Nursing Students Flow Experience and Clinical Competency in Simulation-based Education -based on Jeffriess Simulation Model* [master's thesis]. Seoul, South Korea: Sungshin University; 2016: 21–24.
32. Engeser S, Rheinberg F. Flow, performance and moderators of challenge-skill balance. *Motivation and Emotion*. 2008;32(3): 158–172. doi:10.1007/s11031-008-9102-4.
33. Cheng A, Rodgers DL, van der Jagt E, Eppich W, O'Donnell J. Evolution of the pediatric advanced life support course: enhanced learning with a new debriefing tool and web-based module for pediatric advanced life support instructors. *Pediatric Critical Care Medicine*. 2012;13(5): 589–595. doi:10.1097/PCC.0b013e3182417709.
34. Hur HK, Park SM. Effects of simulation based education, for emergency care of patients with dyspnea, on knowledge and performance confidence of nursing students. *The Journal of Korean Academic Society of Nursing Education*. 2012;18(1): 111–119. doi:10.5977/jkasne.2012.18.1.111.
35. Smith SJ, Farra SL, Ulrich DL, Hodgson E, Nicely S, Mickle A. Effectiveness of two varying levels of virtual reality simulation. *Nursing Education Perspectives*. 2018;39(6): e10–e15. doi:10.1097/01.NEP.0000000000000369.
36. Kooperman P. *Writing Short Film Scripts: A Student Guide to Film-Making*. Melbourne, Australia: Insight Publications; 2011.
37. Jung BS. Military drill instructors' effective teaching behaviors perceived by the military cadets. *Korean Journal of Military Art and Science*. 2016;72(1): 31–67.
38. Havola S, Haavisto E, Mäkinen H, Engblom J, Koivisto JM. The effects of computer-based simulation game and virtual reality simulation in nursing students' self-evaluated clinical reasoning skills. *Computers, Informatics, Nursing: CIN*. 2021;39(11): 725–735.
39. Kim SK, Eom MR, Park MH. Effects of nursing education using virtual reality: a systematic review. *The Journal of the Korea Contents Association*. 2019;19(2): 661–670. doi:10.5392/JKCA.2019.19.02.661.
40. Plotzky C, Lindwedel U, Sorber M, et al. Virtual reality simulations in nurse education: a systematic mapping review. *Nurse Education Today*. 2021;101: 104868. doi:10.1016/j.nedt.2021.104868.
41. Siah CJ, Lim FP, Lim AE, Lau ST, Tam W. Efficacy of team-based learning in knowledge integration and attitudes among year-one nursing students: a pre-and post-test study. *Collegian*. 2019;26(5): 556–561. doi:10.1016/j.colegn.2019.05.003.
42. Lin HC, Hwang GJ, Chang SC, Hsu YD. Facilitating critical thinking in decision making-based professional training: an online interactive peer-review approach in a flipped learning context. *Computers & Education*. 2021;173: 104266. doi:10.1016/j.compedu.2021.104266.
43. Park MK, Kim SK. Structural equation modeling on clinical decision making ability of nurses. *Journal of Korean Academy of Nursing*. 2019;49(5): 601–612. doi:10.4040/jkan.2019.49.5.601.
44. Offredy M, Meerabeau E. The use of 'think aloud' technique, information processing theory and schema theory to explain decision-making processes of general practitioners and nurse practitioners using patient scenarios. *Primary Health Care Research & Development*. 2015;6(1): 46–59. doi:10.1191/1463423605pc228oa.