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Research Article

Virtual reality in nursing education 3D intravenous catheterization E-learning: A randomized controlled trial

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Background: The use of virtual reality in nursing student training for intravenous catheterization and fluid delivery was investigated.

Methods: In this experimental study, 29 students were part of the experimental group while 27 were in the control group. The application was presented to the experimental group using virtual reality technology and to the control group using an intravenous injection arm model.

Results: A statistically significant difference was found between the Intravenous Catheter Application and Fluid Delivery Skills Checklist scores of the students in the experimental and control groups. According to the Bondy Evaluation Scale, there was a statistically significant difference between the students who were at the “supervised” level in the experimental and control groups.

Conclusion: Virtual reality technology was found effective as a teaching method in the development of intravenous catheter application and fluid delivery skills. An increase in its use in nursing training is recommended.

Keywords: virtual reality; simulation; nursing education; e-learning; IV catheterization

1. Intraduction

The traditional education system cannot meet the increasing expectations of society and the changing information needs of the current age. Given the rapid changes in technology, the need for new teaching methods is increasing (Boztepe & Terzioğlu, 2013). In nursing education, new training methods and techniques are needed so that psychomotor skills can be developed outside of clinical settings (Weaver, 2011). Simulation-based learning in nursing education creates a learning environment where students can experience real-life situations more effectively (Edeer & Sarıkaya, 2015; Weaver, 2011).

The types of simulations used in nursing education include models with low technological features, standardized patients playing a role, computer-aided simulations, virtual reality simulations used to learn complex functions, and hybrid simulations (Edeer & Sarıkaya, 2015). Virtual reality technology allows students to use, reapply, or repeat the simulation application from any place, at any time, and as many times as desired. Computer-assisted simulation reduces the cost of using high-validity simulation, and there are many types of haptic systems, three-dimensional (3D) designs, top-level virtual reality avatars, and second life applications available (Edeer & Sarıkaya, 2015; Taveira-Gomes et al., 2016). The strength of such

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training lies in its ability to effectively enable the recreation and visualization of the most complex healthcare environments through virtual reality (Damassa & Toby, 2017).

Today's generation of students has grown up with digital media. They are impatient, get bored quickly, and constantly wait for feedback and rewards. Consequently, virtual reality technologies need to be integrated into the health sciences education curriculum (Bradshaw, 2014; DiLullo et al., 2011). DiLullo et al. (2011) reported that students nowadays are predisposed to learning styles that are achieved using developing technologies and available resources (DiLullo et al., 2011). It is especially difficult for health workers to transfer theoretical knowledge into practical applications. This is why the implementation of virtual reality applications has become a popular practice among educators to provide access to many participants in a short amount of time. Jenson and Forsyth (2012) stated in their study showing the importance of virtual reality simulation, stated that when students understand the process, it boosts their self-confidence. Virtual reality simulation includes simple, adaptable teaching approaches similar to real events in a safe environment, thus enhancing the capacity to address the complexity of training in contemporary health situations (Jenson & Forsyth, 2012). A number of studies have shown that when computer-aided simulation is used in nursing education, students evaluate their training performed with virtual reality applications as positive, and effective results are obtained with respect to critical skills (Foronda et al., 2016; Lu et al., 2009; Pun et al., 2016; Smith & Hamilton, 2015). Nursing instructors are expected to integrate technology into teaching strategies and implement non-traditional methods to support the training of professionals who are well-equipped to provide qualified nursing care (Işık & Kaya, 2011). The published educational standards of the World Health Organization (WHO), the American Association of Nursing Schools (AACN), and the National Council of State Boards of Nursing (NCSBN, 2005) all recommend that simulation methods be included to support the learning process in nursing education and facilitate the training of students (AACN, 2014; NCSBN, 2005; WHO, 2009). However, the use of simulation in nursing education is still not at the desired level globally. More studies similar to ours are needed to prove its efficacy (AACN, 2014; NCSBN, 2005; WHO, 2009).

The aim of this study was to determine the effect of using virtual reality technology in nursing student training for intravenous catheterization and fluid delivery.

2. Methods

2.1. Study design

Experimental research was conducted to investigate the effect of implementing virtual reality technology at the developmental level of nursing student training on intravenous catheter application and fluid delivery. The guidelines of Consolidated Standards of Reporting Trials (CONSORT) for reporting randomized controlled trials (RCTs) were used to describe the methods. Figure 7 summarizes the study design and flow diagram based on the CONSORT reporting guidelines (Moher et al., 2009).

2.2. Study participants

The research was carried out in the Nursing Department Vocational Skills Laboratory of a state university in between September 2018 and January 2019. The participants of the research are the students who took the theoretical course of the Nursing Department's Principles of Nursing course and experienced the application of psychomotor skills for the first time. They applied IV cannulation or virtual reality simulation for the first time. The size of the sample, determined statistically via power analysis, was a total of 52 students: 26 in the experimental group and 26 in

the control group. According to the power analysis results, the in-group analysis between the application and control groups was calculated to be 100%. All participants were evaluated by a single observer.

2.3. Randomization

The research sample was determined using a simple random sampling method. The students in sections A and B of the course made up the population of the study. A simple random sampling method was used to select 33 students from each section as the research sample. However, some students were not present at the school, and some wished to withdraw from the study. Therefore, finally, 29 students were included in the experimental group and 27 in the control group. A virtual reality technology application was used for students in the experimental group, and an intravenous injection arm model was used for students in the control group.

2.4. Ethical considerations

The Ethics Committee of the relevant institution was consulted for evaluation of the ethical suitability of the study. In the meeting held by the Ethics Commission on 09.10.2017, it was concluded that the study was ethically appropriate (Decree No. 2017/133). Informed consent of the students who agreed to participate in the study was obtained in writing.

2.5. Study instruments

The Student Information Form, the Intravenous Catheter Application and Fluid Delivery Skills Checklist, and the Bondy Rating Scale were used to collect the research data.

2.5.1. Student information form

This form was prepared by the researcher using the literature on the subject to identify the socio-demographic characteristics of the students. The questionnaire consisted of six questions about the socio-demographic characteristics of the students: age, gender, place of residence, whether they graduated school, semester grade point averages, and whether they voluntarily chose the nursing profession.

2.5.2. Intravenous catheter application and fluid delivery skills checklist

The skills checklist includes the implementation steps for intravenous catheterization and fluid delivery. The skills checklist covers standardized implementation initiatives used by experts in the field (Craven et al., 2015; INS, 2011). The checklist consists of 32 application steps, with a maximum score of 100 points.

2.5.3. Bondy rating scale

The 5-step assessment scale developed by Kathleen Nowak Bondy in 1983 was used to evaluate students' performance. Students were evaluated according to the level at which they were able to perform intravenous catheterization and fluid delivery using the following categories: (1) dependent, (2) marginal, (3) assisted, (4) supervised, and (5) independent. Students able to perform at the "independent" level did not require guidance. Those rarely requiring supportive information were assessed to be at the "supervised" level. When frequent physical guidance was required to

support verbal guidance and information, students were considered to be at the “assisted” level. When students needed continuous verbal and frequent physical guidance, they were assessed to be at the “marginal” level. Students who were incompetent at demonstrating the skills were rated as “dependent.”

Competence tools that use rating scales (e.g. Likert-type scales) are a more complex and integrated way of assessing clinical skills and proficiency. Nursing clinical performance involves more than just cognitive skills. The emotional field involves attitudes, opinions, appreciation, and values. Emotional sets and attitudes reflect changes in behavior. The psychomotor field focuses on the development of motor skills. Bondy captures the essence of Bloom’s emotional and psychomotor fields by applying the concept of an increasing hierarchy. The Bondy Rating Scale differs from the Likert type and is therefore recommended for use in performance assessment (Truemper, 2004).

2.5.4. Virtual reality technology (3D IV catheterization e-learning)

The 3D Intravenous (IV) Catheterization e-Learning platform of 3DMedSim GmbH was used for student assessment. The researchers, in association with the software company, prepared the IV catheterization interactive platform in the form of a serious game in accordance with the Infusion Nursing Standards (INS). The platform consists of an x-API compliant mobile application prepared for the use of students and an x-API compliant cloud Learning Management System (LMS), in which training data in this application are recorded. The student has to open the mobile application with his/her own username and password (Figure 1) and perform all the procedures required for IV catheterization on a virtual patient by following the step-by-step instructions in the training module (Figures 2–5).

After the student completes the training module, he/she performs the exam within the application where the intermediate steps are measured and scored (Figure 6). In the examination module, the student is in an environment similar to the training module, but unlike in the training module, no practical guidance is provided in the examination module. The student is expected to follow the correct steps in the correct order. In the event that there are errors in basic steps, such as starting the procedure with missing material or not using a tourniquet, the exam stops at that step and the student has to restart the exam.



Figure 1. 3D IV catheterization e-learning login screen.



Figure 2. Introducing yourself in 3D IV catheterization e-learning.

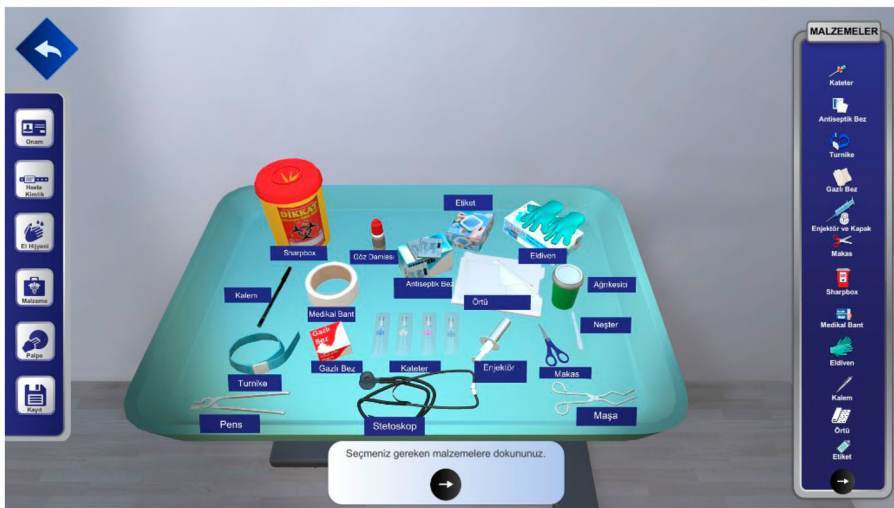


Figure 3. Material preparation in 3D IV catheterization e-learning.

In order to record the measurement and evaluation of the training, the steps taken during the examination are transferred to the cloud LMS at the end of the examination and recorded by the student with a username and password, or retrospective detailed reports of these exams are displayed graphically and viewed in the mobile application by the instructor.

2.5.5. Intravenous (IV) injection arm model

The adult-sized IV injection arm model has a multiple-vessel system designed for vascular access training. This IV injection arm model includes visible and palpable venous vascular structures for



Figure 4. Vein entry angle adjustment in 3D IV catheterization e-learning.

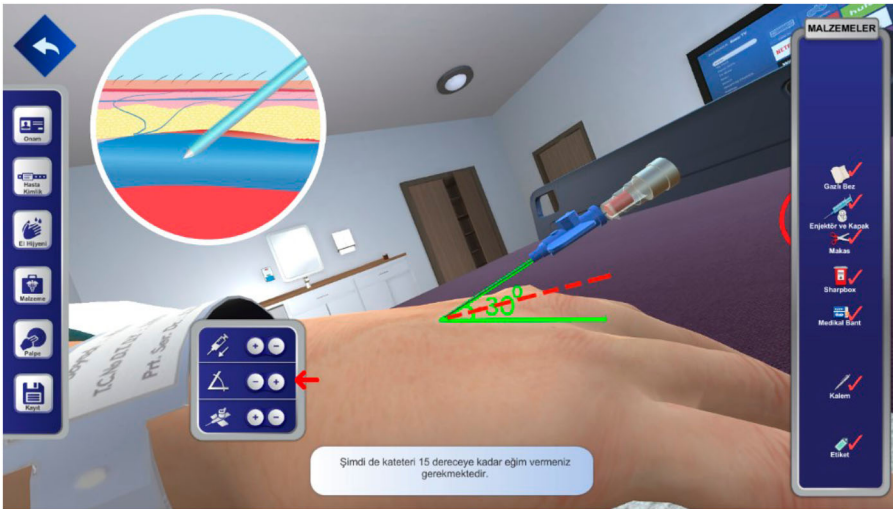


Figure 5. Students iv catheterization practice vein entry in 3D IV catheterization e-learning.

intravenous catheter administration. It provides students with the opportunity to develop skills such as intravenous catheterization, intravenous drug administration, and blood collection. These skills can be applied repeatedly, and the skin and veins can be changed when necessary. This model was used for the control group.

2.6. Data Collection

The data were collected using the Student Information Form, Intravenous Catheter Application and Fluid Delivery Skills Checklist, Bondy Rating Scale, virtual reality technology, and IV



Figure 6. User evaluation results in 3D IV catheterization e-learning.

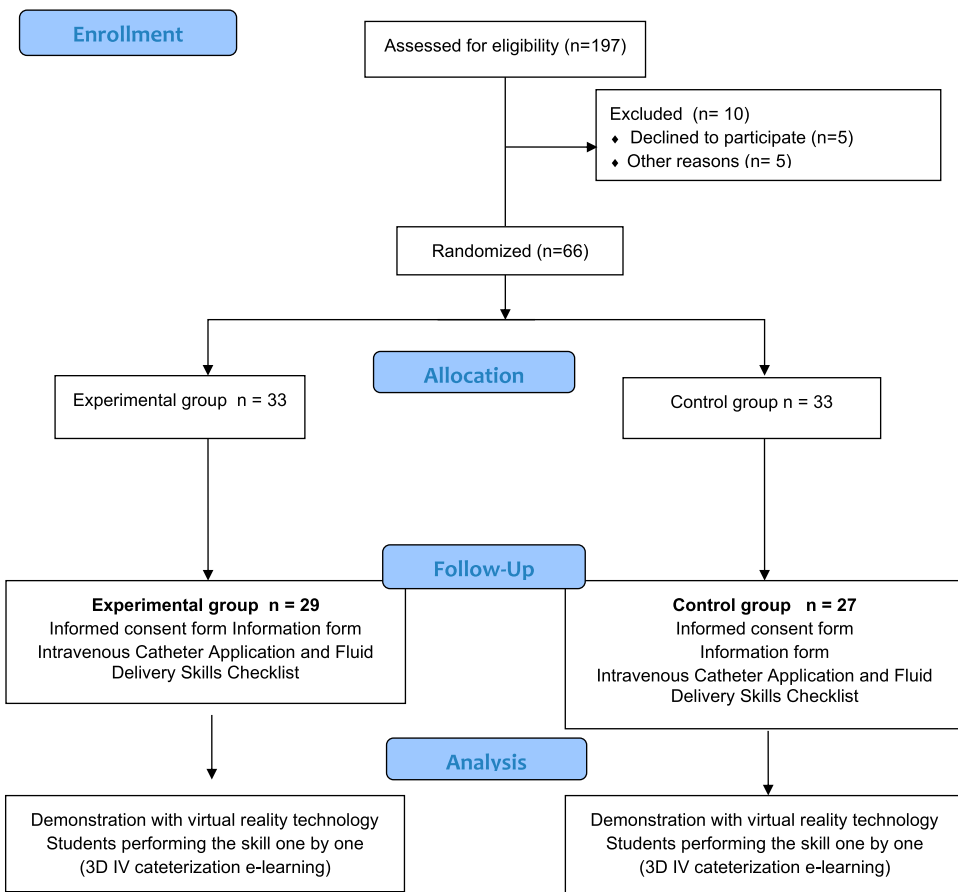


Figure 7. CONSORT 2010 Flow Diagram.

injection arm model. Before the study, both the experimental and control group students had completed six hours of theoretical and ten hours of practical lessons. During practical lessons, all students had performed the procedure on the IV injection arm model. In terms of equal opportunities, all students were exposed to the same conditions.

The students in the control group performed intravenous catheterization and fluid delivery using the IV injection arm model. A two-bed hospital room was set up in the Vocational Skills Laboratory. The IV injection arm model was placed on a bed with a mannequin having low technological features. The students were informed about the characteristics of the patient before starting the application. The students prepared the necessary materials on the treatment tray in the drug preparation room, entered the patient's room, and performed the application.

The students in the experimental group performed intravenous catheterization and fluid delivery using virtual reality (3D IV Catheterization e-Learning). A two-bed hospital room was set up for students in the Vocational Skills Laboratory. The students applied intravenous catheterization skills using virtual reality technology. In addition to the virtual reality technology, an IV injection arm model was installed. After performing the intravenous catheter application in virtual reality, the student completed administering the fluid using the IV injection arm model. For both groups, the students were individually admitted to the laboratory. The application lasted an average of 15–17 min, with a maximum of 25 min. The scheme in Figure 7 presents an outline of the study procedures.

2.7. Data analysis

The data were evaluated using the Statistical Package for Social Science (SPSS) version 21.0. Information, including the age variable of the students, was given as the mean \pm standard deviation. The Shapiro–Wilk test was performed to examine the similarity of the normal distribution. The Mann–Whitney U test, Kolmogorov–Smirnov test, Spearman correlation analysis, and Chi-square test were also used. A statistical significance of $p < 0.05$ was considered acceptable.

3. Results

Out of the students who participated in the study, 69% were female, 31% were male, and the mean age was 19.62 ± 0.82 (min: 18, max: 22) years. The nursing profession had been chosen “intentionally” by 57% and “on recommendation” by 43% of the students in the experimental and control groups.

Table 1 presents a comparison of the students in the experimental and control groups according to the *Intravenous Catheter Application and Fluid Delivery Skills Checklist* score. The score of the students in the experimental group was 88.94 ± 9.22 (min: 68.12–max: 100) and that of the control group was 65.13 ± 11.12 (min: 48.13–max: 87.50). A statistically significant difference was found between the total skill scores of the students in the experimental and control groups ($p = 0.001$). Table 2 shows a comparison of the performance of the students in the experimental and control groups according to the Bondy Rating Scale. When the performance levels were evaluated, the levels in the experimental group were found to be 27.6% “marginal” and “assisted,” 31% “supervised,” and 13.8% “independent.” The levels of the students in the control group were 14.8% “dependent,” 51.9% “marginal,” 29.6% “assisted,” and 3.7% “supervised.” In the experimental group, none were at the “dependent” level, whereas in the control group, none were at the “independent” level. There were no statistically significant intergroup distribution differences among the students of the experimental group ($p > 0.05$). However,

Table 1. Comparison of Intravenous Catheter Application and Fluid Delivery Skills *Check List* scores of experimental and control group students.

Skills Checklist Score	Experimental group (n = 29)			Control group (n = 27)			Statistics
	\bar{X}	SS	Min-Max	\bar{X}	SS	Min-Max	
	88.94	9.22	68.13-100	65.13	11.12	48.13-87.50	Z = -5.693 p = 0.001

Z = Mann-Whitney U test, \bar{X} = Average

Table 2. Comparison of experimental and control group students according to Bondy Rating Scale.

Bondy Rating Scale	Experimental Group		Control group		Statistical Analysis
	n	%	n	%	
Dependent	–	–	4	14.8	–***
Marginal	8	27.6	14	51.9	$\chi^2 = 1.636^* p = 0.201$
Assisted	8	27.6	8	29.6	$\chi^2 = 0.001^* p = 1.00$
Supervised	9	31	1	3.7	$\chi^2 = 6.400^* p = 0.011$
Independent	4	13.8	–	–	–***
Statistical**Analysis	Z = 1.050 p = 0.220		Z = 1.471 p = 0.026		

* χ^2 : Chi-square test **Z: Kolmogorov-Smirnov test *** p-value could not be analyzed.

statistically significant intergroup distribution differences were found among students in the control group ($p = 0.026, p < 0.05$). Table 3 shows the percentages of steps that students in the experimental and control groups most commonly mastered and most commonly skipped during the implementation of intravenous catheterization and fluid administration skills. The

Table 3. Experimental and control group performance results: Application steps of intravenous catheterization and fluid delivery skills.

Application steps	Mastered level			
	Experimental Group		Control Group	
	n	%	n	%
1. The accuracy of nursing records is checked against the physician request using 8 correct drug rules.	28	96.6	2	7.4
2. Hand hygiene is carried out.	28	96.6	23	85.2
3. The prepared materials are placed on the treatment tray.	26	89.7	10	37
4. The curtain and / or door of the room is closed.	26	89.7	5	18.5
5. Identity is determined using two distinctive features.	25	86.2	5	18.5
6. The patient's bedside drug label / drug card / nursing records are compared once again.	26	89.7	4	14.8
7. The IV catheter of the appropriate size is removed from the sterile package.	15	51.7	19	70.4

most frequently applied step by the students in the experimental group (96.6%) and the most frequently neglected step by the students in the control group (7.4%) was "the accuracy of the medical records is checked according to the physician's order by using the eight correct drug rules". 96.6% of the experimental group also applied "hand hygiene is done".

4. Discussion

It was concluded that the students who used virtual reality had higher intravenous catheter application skill points than those who used the intravenous injection arm model. The expectations of the students of this generation and the developing technology have enabled the development of new teaching tools, such as virtual reality. Günay and Zaybak (2018) compared the skill performances of students who received virtual intravenous simulator training with those who received traditional training. Skill performance scores of students with virtual intravenous education were higher, and a significant relationship was found between skill performance scores (Günay & Zaybak, 2018). In another study, Jung et al. (2012) stated that the skill performance score average was higher in the group that received intravenous catheterization training using both traditional and simulation methods (Jung et al., 2012). The results of these studies are similar to those of our study. Many studies show that teaching with virtual reality technology has a positive effect on skill development levels (Bowyer et al., 2005; Tsai et al., 2008; Vidal et al., 2013).

Chang et al. (2002) stated that the use of virtual reality technologies in nursing education has positive effects when it is developed to meet the expectations of users (Chang et al., 2002). In the literature, however, in some studies comparing the IV injection arm model and virtual reality technology method, it was also found that the virtual reality technology method does not affect the skill score and learning attitude (Hwang et al., 2014; Reyes et al., 2008).

In recent years, better and newer methods are being used in teaching, developing, and improving the clinical skills of nursing practices. Virtual reality technology, one of these methods, has been used in the training of nursing practices in recent years. Students today are from Generation Y. The most important feature of this generation is their avid interest in technology. Technology and computers are indispensable for this generation. This is thought to have an impact on the study results.

Chang et al. (2002) reported that the use of virtual reality technologies in nursing education has positive effects when developed to meet user expectations. However, some studies comparing the IV injection arm model and virtual reality technology methods have observed that the virtual reality technology method has no effect on skill scores or learning attitudes (Hwang & Kim, 2014; Reyes et al., 2008). In our study results, it can be thought that this situation arises from individual differences and skills related to technology. Developments in technology are being used via newer and improved methods to teach nursing applications and to upgrade clinical skills. Virtual reality is one of the methods that has been used in nursing applications in recent years. According to the Bondy rating scale, no student from the experimental group performed intravenous catheterization and fluid delivery at the "dependent" level, whereas among students in the control group, 14.8% performed intravenous catheterization and fluid delivery at the "dependent" level. The rate of students in the experimental group who performed at the "supervised" level was significantly higher than students in the control group. The fact that, although they were second-year students, they had not had much practice in the laboratory and clinical areas suggests that they should have had more support from instructors.

Wilfong et al. (2011) conducted a study evaluating the number of IV intervention trials applied to a real patient by nurses given IV catheterization skill training using a virtual intravenous simulator or the traditional method. They found that the nurses in the virtual simulator group were more successful at IV intervention (Wilfong et al., 2011). Bowyer et al. (2005)

reported that there was less pain and hematoma formation in the patients of nursing students who were trained in blood collection skills using the virtual simulation method than in those of the control group students, while successful application attempts were higher in the control group students (Bowyer et al., 2005). Foronda et al. (2016) determined that virtual simulation can be used in isolation or supplementarily to improve and consolidate learning; our research results support these findings.

5. Limitations of the study

In the 2018–2019 spring term, only second year nursing students studying in the nursing department of a state university were included in the study. The applied virtual reality technology only includes the ability to apply intravenous catheters, IV fluids were continued to be given using the arm model, and students' ability to use the technology in an individual capacity was limited in the study. This situation does not affect the research results. It can guide research on the virtual reality of different applications in different studies.

6. Impact Statements

The rapidly changing environment of the current information age necessitates new approaches in nursing training and the effective use of virtual reality in such training has yet to be implemented. Our study demonstrated the viability of this new approach. In addition, during the Covid -19 pandemic, remote and simulated training has become a global priority.

7. Conclusion

This study examined the effects of using virtual reality technology in nursing student training for intravenous catheterization and fluid delivery. It was found that virtual reality technology had a positive effect on students' achievement levels in developing intravenous catheterization and fluid delivery application skills.

In line with these results, the following measures are recommended:

- Including simulation-based training in the curriculum of nursing education institutions and creating simulation laboratory environments with technical equipment for training purposes
- Creating student-centered learning environments using simulation rather than traditional methods, and participating in simulation-related education to aid in the learning of Generation Y students
- Conducting research to investigate the effects of using virtual reality technology on the development levels of other nursing applications
- Conducting research to investigate the effect of simulation-based instructions used in nursing education on skills in clinical settings

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Conception and design, data acquisition or data analysis and interpretation: HY, AD

Drafting of the manuscript or critical revision of the manuscript for important intellectual content: HY, AD

Final approval of the version to be published: HY, AD

Agreement to be accountable for all aspects of the work: HY, AD.

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Disclosure statement

No potential conflict of interest was reported by the authors.

Impact Statements

The use of virtual reality technology and simulation learning is an effective method in psychomotor skill training of students.

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