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The Use of Virtual Reality Simulations in Nursing Education, and Patient Safety

Sule Biyik Bayram and Nurcan Caliskan

Abstract

Nursing education puts theory into practice. Patient safety is indispensable in nursing education. During clinical practice, nursing students make medication errors and have difficulty deciding on what interventions to perform in unusual situations and communicating with patients or other healthcare professionals. All these problems put patient safety at risk. However, "First, do no harm" is a fundamental human right and an ethical principle, which nurses should always consider when they perform interventions. Nursing students can help develop a culture of patient safety through experience in line with their knowledge, skills, and affective goals. Clinical settings can be equipped with real-life laboratories, mannequins, etc. Virtual reality simulations show nursing students what it is like to be in a real-world clinical setting and what problems and risks they may encounter there, and thus, helps them develop skills, build confidence, and prepare for clinical practice. This section addressed the effect of virtual reality simulations on skill development and patient safety in nursing education.

Keywords: nursing education, patient safety, psychomotor skills, simulation, virtual reality

1. Introduction

Nursing education integrates theory and practice to help students develop cognitive, intellectual, affective (attitudes and beliefs), and psychomotor skills and prepare for professional life [1]. Errors in real clinical settings threaten patient safety. Therefore, nursing students should perform primary nursing interventions over and over in laboratories and develop basic psychomotor skills before they enter clinical practice. Simulations replicate real-world situations in which nursing students can gain clinical experience without putting patients at risk [1–3]. Simulations provide effective learning environments where nursing students can gain experience and develop collaboration, management, critical thinking, communication, clinical decision-making, and problem-solving skills without harming patients, and boost their confidence and readiness for real clinical practice [2, 4–6]. Virtual reality (VR), which is a type of simulation, consists of state-of-the-art equipment and augmented-reality interventions. The more similar the simulation is to the real clinical setting, the more motivated and better the students are at developing skills. VR simulations provide nursing students with the opportunity to perform high-risk

and high-cost interventions on virtual patients and gain experience without jeopardizing the safety of real patients [7, 8].

1.1 Psychomotor skills and simulations

Psychomotor skills are coordinated muscle movements governed by conscious mental processes to complete certain tasks [9]. Students develop psychomotor skills by putting theory into practice in lab settings. Instructors first demonstrate the skills and then allow students to put them into practice by themselves and give them feedback on their performance until they become competent [10]. In lab settings, students analyze theoretical knowledge, learn to make observations, and establish a relationship between theory and practice, put their critical thinking and problem-solving skills into practice, and build up confidence [11, 12]. This training teaches them how to perform interventions before clinical practice without risking patient safety [3, 5]. Nursing students without psychomotor skills are more likely to feel insecure and inadequate and make medical errors in clinical practice than those with psychomotor skills [5]. To overcome those problems, it is necessary to help nursing students acquire knowledge and develop skills and put the theoretical knowledge of safe care into practice. Educational technologies are recommended to achieve that goal [13–15]. The students of Generation Z are particularly interested in technology and can easily access information via their personal devices. Therefore, simulations that appeal to the new generation of students have become widespread [5].

Simulations are a safe way for students to perform activities in environments that replicate actual or potential situations. It is effective and engaging because it helps students learn how to use equipment and develop problem-solving and decision-making skills before they step into real clinical settings where training is hard, dangerous, and costly. Simulations are used for pilot and astronaut training and medical education (e.g., cadaver) [16]. Simulations allow nursing students to practice whenever they want without jeopardizing patient safety [17, 18].

1.2 Types of simulations

Two types of simulations are used in nursing education; high-fidelity and low-fidelity. Low-fidelity simulations are three-dimensional organ models, human cadavers, animal models, and simulated and standardized patients. Three-dimensional organ models are anatomical models used to teach students about cardiac functions and how to insert a peripheral IV catheter and perform spinal anesthesia, first aid for injuries, and a breast examination. Simulated and standardized patients are used to help students develop communication skills and to teach them how to take a medical history and perform physical examinations [19]. High-fidelity simulations are image-based, realistic, and interactive patient simulations, VR, and haptic systems. Image-based simulations are computerized image-and video-based simulations that help students learn and develop critical thinking and decision-making skills by themselves [20]. Realistic and interventional simulations, also known as partial task trainers, imitate body parts to teach students particular skills. Some of the realistic and interventional simulations are models for intravascular and foley catheterization, and stitching, and eye and ear as well as ultrasound, clinical cardiology (auscultation), and invasive cardiology (catheterization) simulations. High-tech interactive simulations are computerized virtual patients replicating human anatomy and physiology. Such simulations can breathe, talk, and move their eyes, and have a pulse and heart rate [21]. VR and haptic systems are three-dimensional simulations that feel real and communicate with participants

through computers [22]. Haptic systems are used to tutor students on laparoscopic and endoscopic interventions and to evaluate surgical skills [23].

1.3 Virtual reality

Virtual reality is a computer-generated 3-D simulation that delivers a wide range of sensory information to the user to allow them to interact with objects in a virtual environment and make them feel like they are physically there [15, 24]. VR can be used to help nursing students develop skills in virtual hospital settings.

Interactivity is a key feature of VR, making it more effective than video demonstration. In VR simulations, users wear 3-D glasses and data suits and interact with one another haptically or via a keyboard and a mouse [24–28]. Second Life, Quest Atlantis, Active Worlds, Wonderland, World of Warcraft, and Opensim are 3D/VR platforms, with Second Life being the most popular one [15].

Virtual reality simulations provide students with the opportunity to put interventions into practice on models to overcome problems they may encounter in real clinics [29]. For example, VR can be used to teach nursing students tracheostomy care or urinary catheterization [17, 29]. In this way, they can develop nursing skills on virtual patients and perform interventions smoothly and confidently in real clinics without running the risk of harming real patients [15].

There are two types of VR technologies; immersive and non-immersive. Immersive means "the state of being surrounded, engrossed, and absorbed, the state of being three-dimensional," as well as "plunging into something, and disassociating from reality and entering a virtual world [30]. Immersive VR provides experiences where the user wears a headset and motion-sensing gloves and loses all sense of the real world in a place no bigger than a room. Non-immersive VR is a computer-generated not-fully interactive 3D environment in which the user uses a keyboard, mouse, joystick, and haptic display to control and navigate [31].

1.4 What is virtual reality, and where is it used?

Virtual reality was first used in video games, followed by education, culture, arts, tourism, e-commerce, manufacturing, military and airline, construction, and production [22]. Three-dimensional virtual worlds in education make students more motivated to access information and use it in learning and help them adopt lifelong learning and develop collaboration skills [32]. Virtual reality also allows students to immerse themselves in virtual worlds that replicate the real world and use the materials there and interact with them. It appeals to all senses and promotes effective learning and learning retention. In the field of education, VR was first used in military, flight, and astronaut training [30]. Packy and Marlon was an educational video game developed in 1995 in Japan to teach self-care behavior to children with diabetes [33].

1.5 The use of virtual reality simulations in nursing education

Virtual reality in the field of medical education is defined as a type of computer-based 3D simulation that makes users feel like they are in clinical settings where they can practice skills without putting patients at risk [15]. VR used in physical therapy, and medical and nursing education [15, 17, 34–37] allows students to practice as often as they want and see their own mistakes in safe lab settings [38]. Therefore, such simulations with active engagement improve learning retention and enable participants to learn interactively and analyze problems [39]. VR serves as a bridge between theory and practice in nursing education [40]. Research shows

that VR makes learning fun and active participation possible through feedback and helps nursing students acquire knowledge and develop skills and makes them more motivated and confident [41–44].

Nehring and Lashley [45] mentioned that Phillips [46] was the first to use VR in nursing. Afterward, Merril and Barker [47] developed a prototype for intravenous (IV) catheterization, and then, Skiba [48] used Internet-based interactive virtual environments [45]. The first example of VR in nursing is the CathSim Intravenous Training System (CathSim ITS) developed in 1998. Research shows that CathSim ITS makes participants more motivated and confident and results in a reduction in intervention-related pain, the incidence of hematoma formation, and the number of interventions [49–51]. Students with low anxiety and advanced skills are more likely to perform initiatives quickly and safely. Multiple interventions increase potential risks and jeopardize patient safety.

1.6 Advantages and disadvantages of virtual reality

Virtual reality simulations boost students' concentration, engagement, confidence, motivation, and creativity, and allow them to put theory into practice and learn at their own pace [45]. It also provides them with the opportunity to practice whenever and how often they want in safe and realistic environments without fear of making mistakes and harming patients [52]. Students participating in VR simulations are more likely to become comfortable, confident, and successful in real clinical settings because they learn in an applied format [17, 29]. They can also practice dangerous, costly, and complex interventions that they are less likely to encounter in real clinics [22]. However, VR simulations require interdisciplinary collaboration, and time and money to design scenarios and to train instructors [28]. Besides, prolonged VR use causes dizziness, headaches, and pain when moving the eyes [53].

1.7 Impact of virtual reality simulations on patient safety

Patient safety is about eliminating preventable medical errors that cause harm to patients [54]. High-quality nursing education is a precondition of patient safety. Simulations, in general, and VR, in particular, improve the quality of nursing education and enables students to put theory into practice and develop skills and positive attitudes [15]. Those students are more likely to consider patient safety when performing clinical interventions [55].

Research shows that students who have developed fundamental nursing skills in virtual environments are likely to feel more comfortable and confident and minimize the harm that may result from interventions in real clinical settings [9, 10]. For example, Tag Team Patient Safety Simulation (TTPSS) enhanced nursing students' knowledge and skills and enabled them to provide safe care [56]. VR simulation scenarios should emphasize the principles of patient safety to teach students how to provide safe care in clinics. The Joint Commission International outlines six principles of patient safety [57, 58]. The next section discusses the contribution of VR simulations to nursing education with reference to those principles.

2. Identifying patients correctly

Patient identity should be confirmed before all fundamental nursing interventions. The patient should have at least two of the four identifiers (name, surname, protocol number, and date of birth) as evidence for identification [59]. Skill tests
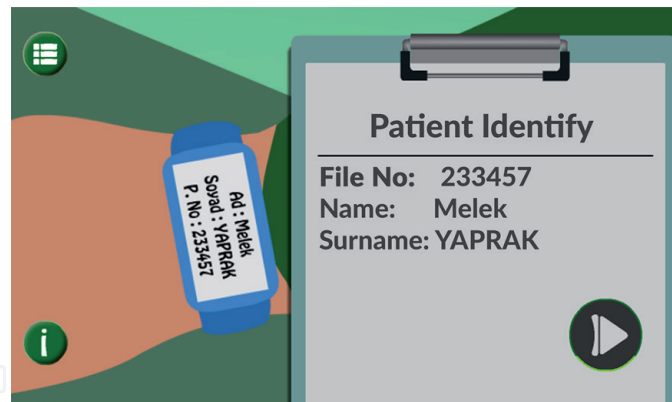
Figure 1.
Patient identify.

and lists in nursing education emphasize the importance of patient identification. Henneman et al. [60] emphasized in his simulation study that verification of patient identity before drug administration is important in ensuring patient safety. In a VR simulation scenario on tracheostomy care, an avatar nurse verified the identity of a virtual patient from her wristband and explained to her the medical procedure to be carried out [61]. The scenario taught the participants how to identify patients correctly. It also highlighted the significance of patient identification as an essential stage of clinical interventions by not allowing the participants who failed to verify the patient's identity to move on to the next stage. Therefore, such scenarios are an effective method for teaching nursing students how to identify patients correctly.

In the studies, the first step in the teaching of skill is the patient character verification process [43, 62, 63]. In a thesis study conducted by Biyik Bayram [62], one of the process steps in the simulation scenario is the patient verification step. Performing the student patient verification process in the VR game will enable him to focus on the same step in the clinic (**Figure 1**) [62]. Koivisto et al. [43], in their study with 166 nursing students, stated that students working with a simulation scenario were able to identify the descriptive characteristics of the patient and plan appropriate nursing interventions. Shibuy et al. [63] in his study with 36 nursing students, it is expected that the student will verify the patient identity in the first step in the 24-item tracheostomy aspiration skill. As seen in the studies, nursing skills practices start with the verification step of the patient identity and the student must ensure the competence in simulation practice to fulfill this task in clinical practice (**Table 1**) [63].

3. Improving effective communication

All healthcare professionals should have effective communication skills to ensure patient safety. Research shows that a lack of or poor communication or miscommunication among patients, nurses, and other healthcare professionals puts patient safety at risk [56, 72]. A lack of communication leads to missing patient data and poor planning, which may result in misdiagnosis and inappropriate treatment [72]. High-fidelity simulations help healthcare professionals develop communication skills. Low-fidelity partial body manikins cannot give feedback, but high-fidelity Simman and virtual patients can speak [64]. VR simulations that can talk enable students to cooperate and make accurate and rapid clinical decisions [73]. Similarly, communicating with virtual patients improve students' communication skills (**Table 1**) [56, 64–66]. VR can be used to teach students how to take patient history,

Patient safety principles	Author/year	Design	Method	Conclusion
1. Identify patient correctly	Shibuya et al./2019 [63]	Three groups	Virtual Reality (VR group) Traditional demonstration (TR group) No intervention (NO group):	The checklist of tracheostomy suctioning skills (Identify patient using name)
	Biyik Bayram/2017 [62]	Randomized controlled	Game Based Virtual Reality (experimental group) Traditional method (control group)	The checklist of tracheostomy care skills (Identify patient using wristband)
	Koivisto et al./2016 [43]	Descriptive study	CareMe® Virtual Reality Game	It has been stated that simulation is effective patient identification.
	Henneman et al./2010 [60]	Retrospective study	Two simulation scenarios	It has been determined that the nursing process game increases students' concentration and experience.
2. Improving effective communication	Fay-Hiller et al./2012 [55]	Review	High-fidelity simulations	Health team communication.
	Guise et al./2012 [65]	Review	High-fidelity simulations	Simulation help healthcare professionals develop communication skills.
	Foronda et al./2016 [65]	Descriptive and mix method	Virtual reality simulation	Strengthens team communication
	Liu et al./2018 [66]	Pilot study	Virtual patients	Virtual patient improves students' communication skills
3. Improving the safety of high-alert medications	Gu et al./2017 [67]	Randomized controlled	Virtual reality simulations	It was stated that the IV drug infusion skills of the students increased. Prevents medication administration errors.
	Lutckar-Flude et al./2012 [68]	Experimental study	The laboratory study (control group) Virtual learning module (experimental group)	It was stated that the students' self-confidence increased.
	Dubovi et al./2017 [69]	Quasi-experimental study (pre-post test)	Virtual Reality Simulation	Learned well about drug management
	Vidal et al./2013 [49]	Quasi-experimental study	Intravenous Virtual Reality Simulation	Intravenous catheter interventions more successfully

Patient safety principles	Author/year	Design	Method	Conclusion
4. Ensuring correct site	Kruglikova et al./2010 [70]	Experimental study	The Accu Touch endoscopy simulator	Virtual Reality colonoscopy simulation performed it more accurately, safely, and quickly.
	Weideman and Culleiton/2014 [71]	Review	Virtual patient	Virtual patient improved students' obstetrics skills.

Table 1.
The studies of contribution of virtual reality simulations on 1,2,3 and 4 patient safety principles.

welcome patients to the clinic, implement the protocol/procedure for discharge, and communicate with other healthcare professionals.

4. Improving the safety of high-alert medications

Nurses frequently administer medications based on the six rights: the right drug, the right patient, the right dose, the right route, the right time, and the right documentation. Nurses who do not comply with those principles or do not know how to administer drugs or have never practiced on a model are more likely to put patient safety at risk [74]. VR simulations give students feedback and help them learn by doing interactively [67]. VR simulations on intravenous drug infusion [67, 68] and administration [70] help students improve the ability to administer medications safely. Dubovi et al. [69] found that nursing students who participated in a VR simulation learned well about drug management. Gu et al. [67] also reported that a VR simulation helped nursing students acquire knowledge on the fundamental principles of asepsis, urinary catheterization, and drug management. Luctkar-Flude et al. [68] found that a VR simulation improved nursing students' IV drug infusion skills. VR simulations are also used to teach nursing students how to notice possible complications after drug administration. For example, Vidal et al. [49] determined that nursing students performed IV interventions more successfully on fewer trials, inflicted less pain on patients, and observed lower incidence of hematoma formation after they participated in a VR simulation (**Table 1**). This result suggests that nursing students participating in VR simulations comply with the six rights of drug administration and intervention steps, and thus, prevent complications, resulting in improved patient compliance and shortened length of hospital stay.

5. Ensuring correct-site, correct-procedure, correct-patient surgery

Surgical errors are among the most common errors that jeopardize patient safety. Virtual patients can be used to inform students on patient safety based on the Surgical Safety Checklist. Students can practice filling out the name and location of the surgery and receiving informed consent before surgery. In this way, they can see their shortcomings and evaluate patient outcomes and learn better through experience [53]. Medical students can manage or perform surgeries on virtual patients that replicate human anatomy and cope with complications [40]. Nurses practicing colonoscopy [70] and obstetric [68] interventions on virtual patients are likely to

have better skills and make fewer errors. Kruglikova et al. [70] found that nurses participating in a VR colonoscopy simulation performed it more accurately, safely, and quickly. Weideman and Culleiton [71]. reported that practicing obstetrics on a virtual patient improved students' skill (**Table 1**). This result shows that virtual patients can be used to help surgical nursing students see their shortcomings and patient outcomes and develop skills.

6. Reducing the risk of health care-associated infections

Infections are the most common cause of death in hospitals. Hand and skin hygiene before each intervention breaks the chain of infection [75]. VR simulations can be used to help nurses develop positive attitudes towards hygiene, resulting in a reduction in the rate of infections. Hand washing is the most effective way to prevent the spread of infections. Nakamura et al. [76] found that simulation scenarios raised students' awareness of hand hygiene and reduced the incidence of catheter-infection. VR simulations improve students' knowledge and skills on decontamination [44, 77] and urinary [4, 17] and intravenous catheterization [10, 34, 78, 79], port catheter injection [35], tracheostomy aspiration [80] and care [29] and nasogastric (NG) tube insertion (**Table 2**) [50, 83]. Failure to comply with asepsis rules in such invasive procedures may cause the spread of infections. Besides, students rarely find themselves in situations where they have to perform those procedures in clinics. They should, nevertheless, practice them in VR simulations so that they would not have anxiety and difficulties in case they have to perform them in clinics [15]. This enables them to put their knowledge and skills into practice more efficiently, resulting in higher-quality care and reduced rates of infections and complications.

In the experimental study conducted by Smith and Hamilton [44] with 20 nursing students, it was stated that computer-based VR application increased urinary catheter skills. In the study conducted by Kardong-Edgren et al. [4] with 31 nursing students, it was stated that haptic VR application increased urinary catheterization skills. These studies highlight the asepsis conditions that the student must comply with in the urinary catheterization procedure. It is aimed that the student fulfills the requirements of asepsis while performing this procedure on the patient. Butt et al. [17] performed urinary catheterization skills with 20 nursing students in a VR environment with a device and gloves they wore on their heads. In a study conducted by Farra et al. [77] with 106 nursing students, it was stated that students' decontamination skills increased. Thus, attention was paid to the prevention of infections. Tsai et al. [34] stated that the frequency of errors of students decreased in the intravenous catheter application they performed in virtual environment with 10 students. In the study conducted by Jung et al. [78], it was stated that the success of the group working with intravenous catheter application and arm model was higher than the others. Tsai et al. [35] increased the knowledge level of port catheter injection of 77 nurses using VR application. Noyudom et al. [80] increased tracheostomy aspiration skills of 35 nursing students working in a virtual environment.

Biyik Bayram and Caliskan [29] stated that 86 nursing students increased tracheostomy aspiration skills with the use of VR. In the study conducted by Chiang et al. [50] with 79 students, it was stated that NG tube insertion application skills increased. NG tube insertion skill is a procedure that must be complied with medical asepsis conditions. Thus, the student understands the distinction between medical and surgical asepsis rules. Similarly, VRapplications are designed to improve NG tube insertion skills in the design study by Choi and his friends.

Patient safety principles	Author/Year	Design	Method	Conclusion
5. Reducing the risk of infections	Smith and Hamilton/2015 [44]	Experimental study	Computer-based virtual reality	The urinary catheterization skills have increased.
	Farra et al./2015 [77]	Quasi-experimental	Virtual reality	The decontamination skills of the students increased.
	Kardong-Edgren et al./2019 [4]	Pilot study	Haptik and virtual reality	Virtual reality is fun and effective in teaching.
	Butt et al./2018 [17]	Pilot study	İmmersive virtual reality	Students' level of knowledge is increased
	Tsai et al./2008 [34]	Pilot study	Virtual reality	Intravenous catheter application skill was advanced.
	Jung et al./2012 [78]	Experimental study	Arm model (A group) Virtual reality (B group) Virtual reality and arm model (C group)	C group was successful compared to other groups.
	Engum et al./2003 [79]	Randomized controlled (Pre-post test)	Arm model (control group) Virtual reality (experimental group)	There was an increase in the intravenous catheter application knowledge scores of the students who used the virtual reality method.
	Tsai et al./2008 [35]	Experimental study (Pre-post test)	Traditional (control group) Virtual reality (experimental group)	Port catheter injection knowledge and skill increased.
	Noyudom et al./2011 [80]	Experimental (Pre-post test)	Virtual Reality	Tracheostomy suctioning knowledge and skill increased.
	Biyik Bayram and Caliskan/2019 [29]	Randomized controlled	Traditional (control group) Virtual reality (experimental group)	Tracheostomy care knowledge and skill increased.
	Chiang et al./2017 [50]	Quasi-experimental	Traditional (control group) Virtual reality (experimental group)	NG tube insertion skill increased.
	Choi et al./2015 [78]	Pilot study	Virtual reality	Thought to guide nurses.
6. Reducing the risk of patient falls	Bursiek et al./2020 [81]	Pilot study	Virtual scenario	Patient falls decreased.
	DeBourg and Prion/2011 [82]	Quasi-experimental study (per-post test)	Simulation	Simulation ensuring a culture of patient safety and preventing falls.

Table 2.
The studies of contribution of virtual reality simulations on 5 and 6 patient safety principles.

7. Reducing the risk of patient harm resulting from falls

Nurses are responsible for providing safe care, which is an indicator of the quality of care [70]. Making sure the bed brakes are locked and raising the bed rails are preventive measures against accidental falls. Therefore, VR simulations are used to teach them. Biyik Bayram and Caliskan [61] used a tracheostomy care scenario in which the student was supposed to lower the bed rails before the intervention and raise them back after the intervention, and if the student skipped the step, she failed to complete it. Such simulations teach students what kind of preventive measures to take against falls. Bursiek et al. [81] reported a decrease in patient falls in clinics with nurses working in virtual scenarios. It was also emphasized that teamwork is effective in preventing patient falls [81]. DeBourg et al. [82] stated that simulation studies were effective in providing patient safety culture of 285 students and preventing falls (**Table 2**). VR simulations have scenarios in which students can keep practicing preventive measures against falls. In this way, they know what to do when they encounter such situations in real clinics. Students should put virtual patients in VR simulations at risk so that they will not jeopardize the safety of real patients because the former can afford the risk, but the latter cannot.

8. Conclusions

Nursing education is an applied type of education. Therefore, students must perform both lab and clinical practice. However, students may put patients at risk because they are inexperienced. Nurses are responsible for establishing a culture of patient safety and protecting patients. Nursing students should participate in activities and lab interventions to become aware of patient safety. Nursing students who do not have much opportunity to participate in lab activities can be provided with VR simulations. Research shows that VR simulations help students gain knowledge and develop collaboration and critical thinking skills, and recognize rare clinical situations, and communicate effectively with patients. Nursing students with those skills can provide safe care, administer medications correctly, and notice changes in their patients. In conclusion, students who participate in VR simulations can provide patient safety in real clinics.

Conflict of interest

No conflict of interest has been declared by the authors.

Glossary of abbreviations

VR   Virtual Reality
IV   Intravenous
NG   Nasogastric
TTPSS   Tag Team Patient Safety Simulation

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