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The use of virtual reality in teaching psychomotor skills and cognitive development in nursing education

Article Type Review

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ABSTRACT

The effectiveness of virtual reality in teaching psychomotor skills not only enhances psychomotor abilities but also strengthens the cognitive development of students. According to Bloom's cognitive taxonomy, virtual reality can focus on analysis and synthesis processes to help students develop higher-order thinking skills. Students can gain experience in cognitive processes such as problem-solving and clinical reasoning through virtual reality applications while translating theoretical knowledge into practical applications. However, alongside these advantages, it is crucial to evaluate the challenges and potential disadvantages that virtual reality introduces to the educational process. Issues such as increased cognitive load, fear of technology, and integration problems into the academic program can adversely affect cognitive development. At the same time, creating an educational environment where nursing students are empowered practically and cognitively requires addressing specific challenges associated with technology-based educational tools. It is essential to emphasize the need for further methodological research and evidence-based studies better to understand virtual reality's role in nursing education.

Keywords: Nursing education, psychomotor skills, virtual reality

Hemşirelik eğitiminde psikomotor beceri öğretiminde sanal gerçekliğin kullanımı ve bilişsel gelişim

ÖZET

Sanal gerçekliğin psikomotor beceri öğretimindeki etkinliği, sadece psikomotor becerileri değil, aynı zamanda öğrencinin bilişsel gelişimini de güçlendirebilir. Bloom'un bilişsel taksonomisine göre, öğrencilerin yüksek seviyeli düşünme becerilerini geliştirmeleri için sanal gerçeklik, analiz ve sentez süreçlerine odaklanabilir. Öğrenciler, sanal gerçeklik uygulamaları aracılığıyla teorik bilgilerini klinik uygulamaya dönüştürürken, problem çözme yetenekleri ve klinik düşünme becerileri gibi bilişsel süreçler üzerinde de deneyim kazanabilirler. Ancak, bu avantajların yanında, sanal gerçekliğin eğitim sürecine getirdiği zorlukları ve potansiyel dezavantajları da değerlendirmek kritiktir. Bilişsel yükün artması, teknoloji korkusu ve eğitim programına entegrasyon sorunları gibi konular, bilişsel gelişim üzerinde olumsuz etkilere neden olabilir. Aynı zamanda, hemşirelik öğrencileri için hem pratik hem de bilişsel açıdan güçlendirildikleri, ancak teknoloji tabanlı eğitim araçlarına yönelik belirli zorlukların ele alınması gerektiği bir eğitim ortamı oluşturulabilir. Bu noktada, sanal gerçekliğin hemşirelik eğitimindeki rolünü daha iyi anlamak için daha fazla metodolojik araştırma ve kanıt temelli çalışmalara ihtiyaç olduğunu vurgulamak önemlidir.

Anahtar Kelimeler: Hemşirelik eğitimi, motor beceriler, sanal gerçeklik

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INTRODUCTION

Psychomotor skill acquisition is one of the paramount components of nursing education. While simulated clinical practices in skill laboratory environments have certain significant limitations, they are widely recognized as among the most effective methods for acquiring clinical psychomotor skills. Various simulation scenarios are employed in clinical settings to integrate clinical and theoretical knowledge to attain proficiency levels in psychomotor skills.[1] It is acknowledged that psychomotor skills entail a range of complex components, including physical movement, coordination, and motor abilities (such as repetition of application, speed, precision, and procedural knowledge)[2]. Therefore, while the development of psychomotor skills through traditional methods in laboratory/clinical practices is often considered the gold standard, more is needed in preparing students for the role of a qualified nurse due to the gap between theoretical knowledge and clinical application in education[3-5]. Advancements in health technology have paved the way for the development of virtual or artificial technologies to enhance students' proficiency in psychomotor skills. These technologies have facilitated the utilization of various simulation methods in skill laboratories to help students acquire competence in psychomotor skills[6]. Thus, it is stated that by integrating simulation methods created using virtual technology into clinical practices, significant contributions can be made to bridging the gap between theoretical knowledge and clinical application without creating real-life situations that would pose a considerable risk.[4,5,7]. Therefore, simulation-based education that reflects real-life conditions allows students to experience competency-based clinical and skill applications in a safe environment[7]. In this regard, simulation applications are utilized as a significant educational strategy in nursing education to develop clinical skills, integrate theory with practice, and avoid negative experiences by students[7,8]. Virtual reality (VR) is a simulation method that facilitates learning and initiates an innovative and modern era in healthcare education due to its ability to provide application opportunities even in the most complex and intricate case scenarios[9]. This article discusses the significance of utilizing virtual reality in teaching psychomotor skills, an essential dimension of nursing education.

The Use of Simulation and Virtual Reality in Teaching Psychomotor Skills:

In skill laboratories, within the scope of nursing education, manikins, task trainers, and live human actors (simulated patients) are utilized to implement clinical scenarios aligned with learning objectives[10]. Parallel to the latest technological advancements, in addition to these simulation applications, low-fidelity to high-fidelity simulator manikins, various computer-based simulation software, haptic simulations, and virtual reality applications are commonly used today[10-12]. In addition, integrating face-to-face education with computer-based simulation and software applications using the "serious games" technique is acknowledged as an innovative approach in health education[13]. Simulation applications, noted to be closely aligned with experiential learning theory in the literature, are highlighted to offer significant advantages such as providing students with experiential learning opportunities, enabling them to identify what could be done differently during application, and actively engaging them in skill practices[1].

However, in virtual reality (VR) applications, potential disadvantages include experiencing feelings such as fear of technology, increased cognitive load, pedophobia (fear of dolls or mannequins), and mannequin phobia, which can be seen as obstacles to learning[1]. On the other hand, there are organizational barriers such as the difficulty of integrating it into the nursing curriculum, equipment costs, providing suitable environments, and ensuring sufficient personnel, which limit opportunities for students to participate in such activities[14-16]. As virtual reality (VR) technology continues to advance rapidly, nurse educators also need to have the necessary skills and knowledge to effectively integrate such technologies into a comprehensive simulation program within a nursing curriculum to enhance the success level of simulation programs[17].

Cognitive Development Using Virtual Reality

Utilizing Virtual Reality (VR) in nursing education increases cognitive processes during psychomotor skill practices[18]. In a systematic meta-analysis involving 1470 participants, VR training, based on Bloom's taxonomy, has shown a significant increase in practical knowledge among nurses and nursing students[18]. According to Bloom's theory, cognitive knowledge acquisition occurs in three stages: understanding, application, and analysis[19]. Bloom's taxonomy is widely utilized in nursing education to support the process of knowledge acquisition through VR while encouraging nursing students to think critically and solve problems throughout their educational journey[20]. VR encompasses educational approaches that support advanced cognitive abilities in Bloom's cognitive domains, such as creative and critical thinking, problem-solving, and multiple intelligences[20-21]. On the other hand, it has been noted that the realism and immersive nature of simulated VR environments enhance students' comprehension levels and learning capacity[18]. In the literature, it is indicated that experiencing the learning process of psychomotor skills through an interactive simulation development application enhances motivation and facilitates learning during skill application[13]. VR provides users numerous opportunities, such as offering an

innovatively and engagingly designed virtual environment, enabling interaction with this environment, and facilitating learning experiences[1,15].

Virtual reality is a more effective learning tool in nursing education than simulation-based methods[21]. Virtual patients allow nursing students to understand educational concepts, principles, and new information better cognitively[21]. Nursing students understand how to address problems appropriately during VR simulations and assess whether their theoretical knowledge is sufficient for providing patient care in clinical settings[22]. Therefore, VR programs are necessary not only to supplement traditional education but also to enhance learning materials[23]. These created virtual environments provide an excellent opportunity for students to naturally encounter errors in skill practices, delve into deeper thinking, and enhance their learning[17,16]. Moreover, in VR applications, due to the opportunity for students to repeatedly practice psychomotor skills, their awareness of the outcomes of their practices increases, allowing them to gain experience in various clinical decision-making processes[16]. In the study conducted by Ulrich et al., it is emphasized that students, particularly in nursing and related healthcare education, achieve success, especially in high-risk, invasive skills[17]. The topic of how VR applications mainly affect psychomotor skills encompasses the neurophysiological processes of the brain and is explained through the development of procedural memory[24,25]. Procedural (judgment-making) memory is a type of long-term memory that pertains to how a psychomotor skill is performed. For instance, in intramuscular injection practices, mirror neurons in the psychomotor cortex fire when an activity resulting in novel pathways occurs in a person's brain[17]. This phenomenon leads to more learning through practice during learning activities than passive observation[17]. By forming these new pathways in the brain, VR applications facilitate the formation of procedural memory in students, making it easier to retain learned content and providing opportunities to perform activities[17]. Learning a psychomotor skill requires the integration of cognitive understanding and rationale. However, students often focus on memorizing the steps of a skill rather than understanding its cognitive aspects[25]. In the study conducted by Ulrich et al.[17], it was noted that students could gain experience in a new psychomotor skill when they experienced virtual reality and visualizing the decontamination procedure facilitated the learning process. According to the results of qualitative and quantitative studies conducted in this research, students' simulated reality experience was evaluated across three themes: learning process, learning efficacy, and learning activity. Positive feedback was obtained from students during focus group discussions[17].

The Applications of Virtual Reality in Psychomotor Skill Education

When examining the studies conducted on virtual reality integrated into basic skills education, it is observed that they frequently focus on the acquisition of psychomotor and challenging invasive skills such as pain management, urinary and intravenous (IV) catheterization, tracheostomy care, nasogastric tube insertion, blood sampling, port catheter injection, and wound dressing[26-38] (Table 1). When the results of these studies are evaluated, it is found that students exhibit high levels of confidence and satisfaction in their psychomotor and skill performance. Additionally, negative emotions such as fear, anxiety, and anxiety are found to be significantly low during applications[26-37]. Information regarding the objective assessment of the impact of virtual reality (VR) on the proficiency level of psychomotor skills is relatively limited in the literature[1]. Although studies emphasize the positive outcomes of skill practices conducted with virtual reality (VR), it is observed that the skill performance scores obtained after the application are not specified[23,29,35-38]. In a systematic review conducted by Rourke[1] evaluating the use of virtual reality (VR) in the acquisition of clinical psychomotor skills by student nurses, it was noted that while VR applications have a preferable potential compared to traditional simulation practices, there is a need to develop a common language and consensus regarding more concrete, conceptualized, and outcome-oriented approaches for assessing psychomotor skills and facilitating skill acquisition. Factors such as limited resources in skills laboratories and the absence of a requirement for practice in laboratory conditions make using virtual reality (VR) in teaching psychomotor skills appealing. Additionally, it is necessary to assess this new technology's feasibility and cost implications, whether virtual reality is supported as an educational model within nursing curricula, and its effectiveness as an educational method.

CONCLUSION

Nursing education ensures competence in theoretical knowledge and clinical skill applications, essential for delivering expected quality care. In this regard, VR applications in nursing education are recommended because they can create a hands-on learning environment by integrating cognitive, affective, and psychomotor skills. VR systems allow students to repeat actions until the correct application is achieved, thereby reducing erroneous attempts in clinical practice and enhancing patient safety. Moreover, they support students' cognitive development. Although literature studies in this field are still in the early stages, findings from this review suggest that VR can offer significant perspectives for psychomotor skill acquisition, effectiveness, and contribution to cognitive development in the future. More evidence-based research with high methodological quality is needed to strengthen confidence in this conclusion.

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Table 1. Research using virtual reality

Author, Year	Participants	Design	Education and VR model	Psychomotor skills	Results
Liu et al[39]., 2023	Nurses	Systematic review study	Meta-analysis. BMC Medical Education	Specialized care	Effectiveness of virtual reality in nursing education
Zhong[40], 2021	New graduate nurses	Quasi-experimental study	Traditional learning methods	Specialized care	Emergency response-ability: It has been stated that self-learning ability has increased.
Chang[41], 2021	Nurses	Quasi-experimental study	Traditional learning methods	Special care	Learning success, attitudes, satisfaction, And problem-solving skills are stated.
Huang[42], 2020	New graduate nurses	Quasi-experimental study	Traditional flipped learning mode	Skill practice	Decision-making, learning achievement performance, problem-solving tendency: It was determined that meta-cognition tendency and classroom participation were at high levels.
Zhong[43], 2021	Nurses	Randomized controlled trial	Traditional education for three months	Specialized care was discussed.	Emergency care capacity, theoretical evaluation, technical skills, and Preparation issues for possible pandemics were
Luo[44], 2021	New graduate nurses	Quasi-experimental study	Case Study	Clinical reasoning;	Specialty care and trust yourself; satisfaction level was determined.
Chao[45] ,2021	Nurses	A randomized controlled trial study.	Nurse Education	Nursing Skill Competence:	The effects of an immersive 3D interactive video program on Improving Student
Biyik Bayram & Çalışkan[37], 2019	Nursing students	Randomized Controlled Study	Non-immersive mobile VR game	Tracheostomy care skills	It has been determined that the knowledge and skill levels of students who use the VR game have increased.
Butt[30] et al., 2018	Nursing student	Randomized Controlled Study / Pilot Study	Immersive touch VR gameplay	Urinary catheterization skills	Students working with this application stated that the application was exciting and fun and that their knowledge level increased.
Edgren[46] et al., 2019	Nursing student	Randomized Controlled Study / Pilot Study	Immersive touch VR gameplay	Urinary catheterization skills	It has been stated that the game is fun and effective in teaching.
İsmailoğlu & Zaybak[33], 2018	Nursing Students	Randomized Controlled Study	Non-immersive computer-based VR	Intravenous catheterization skills	It has been stated that it increases students' skills and self-confidence and reduces their fears.
Gu[47] et al., 2017	Nursing Students	Randomized controlled trial	Non-immersive PC-based VR game	Asepsis, urinary catheterization, and drug administration	It has been stated that students' knowledge and skills have increased.
Pun[48] et al., 2016	Nurses	Randomized controlled trial	Traditional learning methods	Procedural Skills and Expertise Care	It has been stated that the level of knowledge and skills has increased.
Curl[49] 2016	Nursing Students.	Experimental Study	Integrated Simulation	Clinical Experiences	Effectiveness of Integrated Simulation and Clinical Experiences Compared to Traditional Clinical Experiences for Nursing Students.
Smith & Hamilton[29], 2015	Nursing Students	Experimental Study	Non-immersive computer-based VR	Urinary catheterization skills	It has been stated that application skills have increased.
Boada[50] et al., 2015	Nursing Students	Randomized controlled trial	Non-immersive computer-based VR	Cardiopulmonary resuscitation	It has been determined that the game increases student skills and motivation.

Table 1. Continues

Author, Year	Participants	Design	Education and VR model	Psychomotor skills	Results
Tsai[51] et al., 2015	Nursing Students	Randomized controlled trial	Non-immersive computer-based VR	Chronic obstructive pulmonary disease care	It has been determined that the skills of students playing virtual reality games increase and their anxiety decreases.
Farra[52] et al.,2015	Nursing Students	Quasi-experimental study	Non-immersive computer-based VR	Decontamination	It was stated that students' skill levels in decontamination practices increased.
Ulrich[17] et al., 2014	Nursing Students	Randomized controlled trial	Non-immersive computer-based VR	Decontamination	It was stated that students' knowledge and skills increased, and the knowledge was permanent.
Chia[53], 2013	Nursing Students	Qualitative study	Non-immersive computer-based VR	Chronic obstructive pulmonary disease care	It was stated that the students' knowledge level on this subject increased, and the game was enjoyable.
Buttussi[54] et al., 2013	Nursing Students	Randomized controlled trial	Non-immersive computer-based VR	Cardiopulmonary resuscitation	As a result of the research, it was stated that students' knowledge and skills increased.
Roh[55], 2013	Nurses	Randomized controlled trial	Mannequin-based simulation with SimMan	special care	Information; self-sufficiency; satisfaction
Luctkar[56] et al., 2012	Nursing Students	Experimental study	Non-immersive computer-based VR	Intravenous drug infusion	It was stated that students' self-confidence increased
Mosalanejad[57] et al.,2012	Nursing Students	Quasi-experimental study	Non-immersive computer-based VR	Basic nursing skills	It was stated that skill points increased
Wilfong[58], 2011	Nurses	Randomized controlled trial	Traditional learning methods	Basic nursing skills	It has been stated that successful intravenous catheter applications and the number of attempts decreased.
Tsai[35] et al., 2008	Nurses	Quasi-experimental study	Non-immersive computer-based VR	Port catheter injection	It was stated that the knowledge and skill levels of nurses increased.
Tsai[59] et al., 2008	Nursing Students	Randomized controlled trial	Non-immersive computer-based VR	Intravenous catheterization skills	Participants reported a decrease in the frequency of errors and procedure time with intravenous catheter application.
Engum[36] et al., 2003	Nursing Students	Randomized controlled trial	Non-immersive computer-based VR	Intravenous catheterization skills	It was stated that there was an increase in the knowledge scores of students who used the VR method.
Chang[60], 2002	Nurses	Randomized controlled trial	Conventional teaching method with a plastic arm	skill practice	It has been stated that experience increases intravenous cannulation performance in VR learning.
Reznek[61] 2002	Nurses	Simulator	virtual reality intravenous	Intravenous insertion simulator	Evaluation of the educational effectiveness of a virtual reality intravenous insertion simulator.

REFERENCES

1. Rourke S. How does virtual reality simulation compare to simulated practice in the acquisition of clinical psychomotor skills for pre-registration student nurses? A systematic review. *Int J Nurs Stud.* 2020;102:103466. http://dx.doi.org/10.1016/j.ijnurstu.2019.103466
2. Fotheringham D. Triangulation for the assessment of clinical nursing skills: A review of theory, use, and methodology. *Int J Nurs Stud.* 2010;47(3):386-91. http://dx.doi.org/10.1016/j.ijnurstu.2009.09.004
3. Huisman J, Case JM, eds. Researching Higher Education International Perspectives On Theory, Policy, and Practice. Routledge; 2016. Accessed January 11, 2024. https://capitadiscovery.co.uk/port/items/1228195
4. Josephine SN. The theory-practice gap and skill acquisition: An issue for nursing education. *Collegian.* 2011;18(2):93-8. http://dx.doi.org/10.1016/j.colegn.2010.04.002
5. Monaghan T. A critical analysis of the literature and theoretical perspectives on theory–practice gap amongst newly qualified nurses within the United Kingdom. *Nurse Educ Today*. 2015;35(8):e1-7. http://dx.doi.org/10.1016/j.nedt.2015.03.006
6. Unver V, Basak T, Watts P, Gaioso V, Moss J, Tastan S, et al. The reliability and validity of three questionnaires: The Student Satisfaction and Self-Confidence in Learning Scale, Simulation Design Scale, and Educational Practices Questionnaire. *Contemp Nurse*. 2017;53(1):60-74. http://dx.doi.org/10.1080/10376178.2017.1282319
7. Lewis R, Strachan A, Smith MM. Is high fidelity simulation the most effective method for the development of non-technical skills in nursing? A review of the current evidence. *Open Nurs J.* 2012;6:82-9. http://dx.doi.org/10.2174/1874434601206010082
8. Cant RP, Cooper SJ. Simulation-based learning in nurse education: Systematic review. *J Adv Nurs.* 2010;66(1):3-15. http://dx.doi.org/10.1111/j.1365-2648.2009.05240.x
9. Loukas C, Nikiteas N, Kanakis M, Moutsatsos A, Leandros E, Georgiou E. A virtual reality simulation curriculum for intravenous cannulation training. *Acad Emerg Med.* 2010;17(10):1142-5. http://dx.doi.org/10.1111/j.1553-2712.2010.00876.x
10. Weller JM, Nestel D, Marshall SD, Brooks PM, Conn JJ. Simulation in clinical teaching and learning. *Med J Aust.* 2012; 196(9):594. http://dx.doi.org/10.5694/mja10.11474
11. Gündoğdu H, Dikmen Y. Simulation in nursing education: VR and Haptic Systems. *J Hum Rhythm.* 2017;3(4):172-6.
12. Donovan LM, Argenbright CA, Mullen LK, Humbert JL. Computer-based simulation: Effective tool or hindrance for undergraduate nursing students? *Nurse Educ Today.* 2018;69:122-7. http://dx.doi.org/10.1016/j.nedt.2018.07.007
13. Wang RB, DeMaria S, Goldberg A, Katz D. A systematic review of serious games in training health care professionals. *Simul Healthc.* 2016;11(1):41-51. http://dx.doi.org/10.1097/SIH.0000000000000118
14. Al-Ghareeb AZ, Cooper SJ. Barriers and enablers to the use of high-fidelity patient simulation manikins in nurse education: an integrative review. *Nurse Educ Today.* 2016;36:281-6. http://dx.doi.org/10.1016/j.nedt.2015.08.005
15. Johnson-Glenberg M. Immersive VR and education: Embodied design principles that include gesture and hand controls. *Front Robot AI.* 2018;5:81. http://dx.doi.org/10.3389/FROBT.2018.00081
16. Verkuyl M, Atack L, Mastrilli P, Romaniuk D. Virtual gaming to develop students' pediatric nursing skills: A usability test. *Nurse Educ Today.* 2016;46:81-5. http://dx.doi.org/10.1016/j.nedt.2016.08.024.
17. Ulrich D, Farra S, Smith S, Hodgson E. The student experience using virtual reality simulation to teach decontamination. *Clin Simul Nurs.* 2014;10(11):546-53. http://dx.doi.org/10.1016/j.ecns.2014.08.003.
18. Efendi D, Apriliyasari RW, Prihartami Massie JGE, Wong CL, Natalia R, Utomo B, et al. The effect of virtual reality on cognitive, affective, and psychomotor outcomes in nursing staffs: systematic review and meta-analysis. *BMC Nurs.* 2023;22(1):170. https://doi.org/10.1186/s12912-023-01312-x
19. Armstrong P. Bloom's Taxonomy. Vanderbilt University Center for Teaching. Published 2010. Available from: https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy.
20. Chen YL. The effects of virtual reality learning environment on student cognitive and linguistic development. *The Asia-Pacific Education Researcher.* 2016;25(4):637-46.
21. Forsberg E, Ziegert K, Hult H, Fors U. Assessing progression of clinical reasoning through virtual patients: An exploratory study. *Nurse Educ Pract.* 2016;16(1):97-103.
22. Nascimento JDSG, Siqueira TV, Oliveira JLG, Alves MG, Regino DDSG, Dalri MCB. Development of clinical competence in nursing in simulation: the perspective of Bloom's taxonomy. *Rev Bras Enferm.* 2021;74(1):e20200135.
23. Lange AK, Koch J, Beck A, Neugebauer T, Watzema F, Wrona K, Dockweiler C. Learning with virtual reality in nursing education: Qualitative interview study among nursing students using the unified theory of acceptance and use of technology model. *JMIR Nursing.* 2020;3(1):e20249. http://dx.doi.org/10.2196/20249
24. Kandel ER. In search of memory: The emergence of a new science of the mind. New York, NY: W. W. Norton Company; 2006. http://dx.doi.org/10.1172/JCI28674
25. McDonald M. The nurse educator's guide to assessing learning outcomes. 3rd ed. Burlington, MA: Jones and Bartlett Learning; 2014. ISBN: 978-1-44-968767-0.
26. Small C, Stone R, Pilsbury J, Bowden M, Bion J. Virtual restorative environment therapy as an adjunct to pain control during burn dressing changes: Study protocol for a randomised

controlled trial. *Trials.* 2015;16:329. http://dx.doi.org/10.1186/s13063-015-0878-8
27. Hua Y, Qiu R, Yao WY, et al. The effect of virtual reality distraction on pain relief during dressing changes in children with chronic wounds on lower limbs. *Pain Manag Nurs.* 2015;16(5):685-91. http://dx.doi.org/10.1016/j.pmn.2015.03.001
28. Jöud A, Sandholm A, Alseby L, Petersson G, Nilsson G. Feasibility of a computerized male urethral catheterization simulator. *Nurse Educ Pract.* 2010;10(2):70-5. http://dx.doi.org/10.1016/j.nepr.2009.03.017
29. Smith P, Hamilton B. The effects of virtual reality simulation as a teaching strategy for skills preparation in nursing students. *Clin Simul Nurs.* 2015;11(1):52-58. https://doi.org/10.1016/j.ecns.2014.10.001.
30. Butt AL, Kardong-Edgren S, Ellertson A. Using game-based virtual reality with haptics for skill acquisition. *Clin Simul Nurs.* 2018;16:25-32. http://dx.doi.org/10.1016/j.ecns.2017.09.010.
31. Jamison RJ, Hovancsek MT, Clochesy JM. A pilot study assessing simulation using two simulation methods for teaching intravenous cannulation. *Clin Simul Nurs.* 2006;2(1):9-12. http://dx.doi.org/10.1016/j.ecns.2009.05.007.
32. Jung EY, Park DK, Lee YH, Jo HS, Lim YS, Park RW. Evaluation of practical exercises using an intravenous simulator incorporating virtual reality and haptics device technologies. *Nurse Educ Today.* 2012;32(4):458-63. http://dx.doi.org/10.1016/j.nedt.2011.05.012.
33. İsmailoğlu EG, Zaybak A. Comparison of the effectiveness of a virtual simulator with a plastic arm model in teaching intravenous catheter insertion skills. *Comput Inform Nurs.* 2018;36(2):98-105.
34. Vidal VL, Ohaeri BM, John P, Helen D. Virtual reality and the traditional method for phlebotomy training among college of nursing students in Kuwait: implications for nursing education and practice. *J Infus Nurs.* 2013;36(5):349-55. http://dx.doi.org/10.1097/NAN.0b013e318243172f
35. Tsai SL, Chai SK, Hsieh LF, Lin S, Taur FM, Sung WH, Doong JL. The use of virtual reality computer simulation in learning port-a cath injection. *Adv Health Sci Educ.* 2008;13(1):71-87. http://dx.doi.org/10.1007/s10459-006-9025-3.
36. Engum SA, Jeffries P, Fisher L. Intravenous catheter training system: Computer-based education versus traditional learning methods. *Am J Surg.* 2003;186(1):67-74. http://dx.doi.org/10.1016/S0002-9610(03)00109-0.
37. Bayram ŞB, Çalışkan N. The Effect of Mobile Game Application on Nursing Students' Knowledge, Motivation and Satisfaction: Tracheostomy Care Example. In 5th National 1st International Nursing Care Congress, 2019.
38. Bıyık Bayram Ş, Çalışkan N. An innovative approach in psychomotor skill teaching for nurses: Virtual reality applications. *J Educ Res Nurs*. 2021; 18(3):356-61.
39. Liu K, Zhang W, Li W, Wang T, Zheng Y. Effectiveness of virtual reality in nursing education: A systematic review and meta-analysis. *BMC Medical Education.* 2023;23(1):710. https://doi.org/10.1186/s12909-023-04662-x
40. Zhong M, Jiang J, Zhang H, Duan X. Combination of flipped learning format and virtual simulation to enhance emergency response ability for newly registered nurses: A quasi-experimental design. *Interactive Learning Environments*. 2021;31(8): 5127-40. https://doi.org/10.1080/10494820.2021.1998138
41. Chang YM, Lai CL. Exploring the experiences of nursing students in using immersive virtual reality to learn nursing skills. *Nurse Education Today*. 2021;97:104670. https://doi.org/10.1016/j.nedt.2020.104670
42. Huang HL, Chou CP, Leu S, You HL, Tiao MM, Chen CH. Effects of a quasi-experimental study of using flipped classroom approach to teach evidence-based medicine to medical technology students. *BMC Medical Education.* 2020;20(1):31. http://dx.doi.org/10.1186/s12909-020-1946-7
43. Zhong M, Jiang J, Zhang H, Duan X. Combination of flipped learning format and virtual simulation to enhance emergency response ability for newly registered nurses: A quasi-experimental design. *Interactive Learning Environments*. 2021;31(8): 5127-40. https://doi.org/10.1080/10494820.2021.1998138
44. Luo Y, Geng C, Chen X, Zhang Y, Zou Z, Bai J. Three learning modalities' impact on clinical judgment and perceptions in newly graduated registered nurses: A quasi-experimental study. *Nurs Health Sci.* 2021;23(2):538-46. http://dx.doi.org/10.1111/nhs.12842.
45. Chao YC, Hu SH, Chiu HY, Huang PH, Tsai HT, Chuang YH. The effects of an immersive 3D interactive video program on Improving Student Nurses' Nursing Skill Competence: A randomized controlled trial study. *Nurse Education Today.* 2021;103:104979. https://doi.org/10.1016/j.nedt.2021.104979
46. Kardong-Edgren S, Breitkreuz K, Werb M, Foreman S, Ellertson A. (2019). Evaluating the usability of a second-generation virtual reality game for refreshing sterile urinary catheterization skills. *Nurse Educator*. 2019;44(3):137-41. https://doi.org/10.1097/nne.0000000000000570
47. Gu Y, Zou Z, Chen X. The effects of vSIM for nursing™ as a teaching strategy on fundamentals of nursing education in undergraduates. *Clinical Simulation in Nursing*. 2017;13(4):194-7. https://doi.org/10.1016/j.ecns.2017.01.005
48. Pun SK, Chiang VC, Choi KS. A computer-based method for teaching catheter-access hemodialysis management. Comput Inform Nurs. 2016;34(10):476-83. http://dx.doi.org/10.1097/CIN.0000000000000262
49. Curl ED, Smith S, Ann Chisholm L, McGee LA, Das K. Effectiveness of integrated simulation and clinical experiences compared to traditional clinical experiences for nursing students. *Nurs Educ Perspect.* 2016;37(2):72-7. http://dx.doi.org/10.5480/15-1647
50. Boada I, Rodriguez-Benitez A, Garcia-Gonzalez JM, Olivet J, Carreras V, Sbert M. Using a serious game to complement CPR instruction in a nurse

faculty. *Computer Methods and Programs in Biomedicine*. 2015;122(2):282-91. https://doi.org/10.1016/j.cmpb.2015.08.006
51. Tsai SL, Chai S, Chuang KH. The effectiveness of a chronic obstructive pulmonary disease computer game as a learning tool for nursing students. *Open Journal of Nursing*. 2015;5:605-12. https://doi.org/10.4236/ojn.2015.57064
52. Farra SL, Smith S, Gillespie GL, Nicely S, Ulrich DL, Hodgson E, et al. Decontamination training. *Advanced Emergency Nursing Journal*. 2015;37(2):125-33. https://doi.org/10.1097/tme.0000000000000059
53. Chia P. Using a virtual game to enhance simulation-based learning in nursing education. *Singapore Nursing Journal*. 2013;40(3):21-26.
54. Buttussi F, Pellis T, Cabas Vidani A, Pausler D, Carchietti E, Chittaro L. Evaluation of a 3D serious game for Advanced Life Support Retraining. *International Journal of Medical Informatics*. 2013;82(9): 798-809. https://doi.org/10.1016/j.ijmedinf.2013.05.007
55. Roh YS, Lee WS, Chung HS, Park YM. The effects of simulation-based resuscitation training on nurses' self-efficacy and satisfaction. *Nurse Education Today*. 2013;33(2):123-8. https://doi.org/10.1016/j.nedt.2011.11.008
56. Luctkar-Flude M, Wilson-Keates B, Larocque M. Evaluating high-fidelity human simulators and standardized patients in an undergraduate Nursing Health Assessment course. *Nurse Education Today*. 2012;32(4): 448-52. https://doi.org/10.1016/j.nedt.2011.04.011
57. Mosalanejad L, Shahsavari S, Sobhanian S, Dastpak M. Note for editor: The effect of virtual versus traditional learning in achieving competency-based skills. *Turkish Online Journal of Distance Education*. 2012;13(2):69-75.
58. Wilfong DN, Falsetti DJ, McKinnon JL, Daniel LH, Wan QCP. The effects of virtual intravenous and patient simulator training compared to the traditional approach of teaching nurses: A research project on peripheral i.v. catheter insertion. *Journal of Infusion Nursing*. 2011;34(1):55-62. https://doi.org/10.1097/nan.0b013e31820219e2
59. Tsai WW, Fung CP, Tsai SL, Jeng MC, Doong JL. The assessment of stability and reliability of a virtual reality-based intravenous injection simulator. *CIN: Computers, Informatics, Nursing*. 2008;26(4):221-6. http://dx.doi.org/10.1097/01.NCN.0000304804.46369.5a.
60. Chang KK, Chung JW, Wong TK. Learning intravenous canulation: A comparison of the conventional method and the CathSim Intravenous Training System. *J Clin Nurs*. 2002;11(1):73-8.
61. Reznek MA, Rawn CL, Krummel TM. Evaluation of the educationa effectiveness of a virtual reality intravenous insertion simulator. *Academic Emergency Medicine*. 2002;9(11):1319-25. https://doi.org/10.1197/aemj.9.11.1319