Virtual Simulation in Nursing Education: A Systematic Review

Jasper Erwin L. Tolarba

Director of Global Standards at CGFNS International Inc., Philadelphia PA.

Abstract

Background: With recent advances in computer and information technology over the last few years, there has been an increase in the use of virtual simulation in the field of nursing education.

Design: Systematic review of experimental, quasi-experimental, and qualitative studies.

Data sources: CINAHL, MEDLINE, PubMed, ERIC, PsychINFO, and ProQuest were searched by title and abstract spanning from January 2010 to December 2020.

Results: Twenty-three studies were included in the narrative summary. Overwhelming evidence from these studies shows a positive impact on student knowledge, skills, affective learning outcomes. Studies were mostly conducted in developed countries perhaps due to the high cost of acquiring this technology in the classroom.

Conclusion: Virtual simulation is highly effective in improving knowledge, skills, and affective outcomes of students. Nursing educators and other stakeholders need to support future initiatives in the advancement of virtual simulation and possible inclusion in the nursing curriculum.

Keywords: Virtual simulation, Virtual reality, Education, Nursing, Systematic review, Technology

Introduction

Traditionally, nursing programs utilize in-person clinical simulation in which students have to be physically present in a clinical lab with a mannequin set-up and students perform clinical skills under the supervision of a nursing faculty. With recent advances in computer and information technology over the last few years, there has been an increase in the use of virtual simulation in the field of nursing education. The need for virtual simulation in nursing education has been further bolstered when the COVID19 pandemic brought all face-to-face classes to a halt and transitioned into remote learning. With this pandemic, virtual simulation is increasingly becoming a cornerstone of clinical training[1]. However, because virtual simulation is relatively new, there is no robust body of knowledge to support its effectiveness in student learning. As a result, regulatory bodies and policymakers are hesitant to accept clinical hours done via virtual simulation as a substitute for traditional clinical experience. However, the Society for Simulation in Healthcare issued a position statement advocating for the replacement of clinical hours usually completed in a healthcare setting with that of virtually simulated experiences during this time of a global health crisis[2].

Virtual simulation is defined as a computer-generated, three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors[3]. There are many advantages to using virtual simulation in nursing education. Students and nursing faculty need not be present to do the clinical skills demonstration or nursing procedure. It allows students to perform the nursing procedure repeatedly without any risk of causing harm to an actual patient. For nursing

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Corresponding author:
Jasper Erwin L. Tolarba,
jaspertolarba@icloud.com

faculty, virtual simulation provides more capability to monitor student performance and provide feedback. It is also relatively easier to standardize the learning content or adjust it to meet the student's level of performance. Some of the drawbacks of virtual simulation include the high cost of setup as well as its maintenance. Also, the absence of human connection and interaction can become a disadvantage because it eliminates personal communication between the student and the faculty. The lack of software flexibility can also be limiting to the educational experience since the program is designed to only do what the software is programmed to do. Despite these disadvantages, the potential of the virtual simulation being a standard inclusion in a nursing curriculum is highly possible in the near future due to the student population becoming more technologically adept and savvy.

Learning through virtual simulation has its underpinnings on experiential learning theory advanced by Kolb[4]. This theory explains that learning happens optimally when students experience it firsthand. Students learn more by doing and those experiences are retained in their mind better compared to when they are mere passive learners. The first two stages of Kolb's theory – i.e., concrete learning and reflective observation – involve understanding an experience. The remaining two stages – i.e., abstract conceptualization and active experimentation – focus on transforming an experience. With virtual simulation, students begin by understanding the theoretical and practical concepts presented in the virtual reality environment. Subsequently, students' level of understanding broadens to a more abstract concept, develop their ideas, and test those ideas through their own investigation. They come out of this learning process more knowledgeable, and it teaches them the skill of how similar complex situations can be handled in a real-life setting when an opportunity presents itself.

The goal of this paper is to evaluate the effectiveness of virtual simulation in nursing education by conducting a systematic review of the literature. The outcomes of interest are knowledge, skills, and attitudes. A study done by Foronda, et al.[5] looked at the virtual simulation in nursing education from a span of 1996-2018. This particular study showed that virtual simulation is an effective pedagogy to achieve learning outcomes. Another study done by Woon, et al.[6] investigated the effectiveness of virtual reality training in improving knowledge among nursing students by doing a systematic review, meta-analysis, and meta-regression for studies done until October 15, 2019. They found that virtual reality may be a viable teaching strategy to improve knowledge acquisition. Since 2018, additional studies related to this have been conducted. This present study provides an up-to-date narrative review of studies from January 2010 until December 2020. In addition, this work extends beyond just looking at how virtual simulation affects the knowledge domain but also considers its impact on the skills and affective domains.

Method

Articles were screened against the inclusion and exclusion criteria for eligibility by two independent reviewers and all discrepancies were resolved by discussion. The selection of the included studies is detailed in the PRISMA flow diagram. Six electronic databases (CINAHL, MEDLINE, PubMed, ERIC, PsychINFO, and ProQuest) were searched by title and abstract for articles published from January 2010 through December 2020. A combination of subject heading terms and keywords were included: (virtual simulation OR virtual reality) AND (nursing OR education OR instruction) AND (knowledge or skills or attitudes). EndNote X9, a reference management software, was utilized to record all citations from the databases and to eliminate duplicates. The inclusion criteria for this review were the use of virtual simulation in nursing education; study designs that were either experimental, quasi-experimental, and qualitative; at least 20 participants per condition; and written in the English language. Articles were excluded if the simulation did not involve virtual technology. Articles were also excluded if the virtual simulation was not used in any teaching context. Studies that were not peer-reviewed (e.g., theses) were also excluded. The author has created a separate list of full-text articles that were reviewed and excluded for specific reasons and can be made available upon request.

Critical appraisal for the selected articles was conducted using the JBI's Critical Appraisal Tool[7].

The reviewers independently appraised the 23 studies using the appropriate JBI's critical appraisal tools and provided an appraisal score to each study. Based on a discussion between the reviewers, the studies were decided as 'good quality' before they were included in the review. Articles that were chosen were those that focus on: 1.) the relationship of virtual simulation in increasing student knowledge, 2.) effectiveness of virtual simulation in improving nursing skills and student competencies, and 3. user experience of virtual simulation in nursing education. A total of 512 potential articles were identified during the initial database search. After removing duplicate articles, 320 articles remained. These 320 articles were screened by titles and abstracts for relevance. After excluding 256 articles that were deemed irrelevant to the topic, 64 full-text articles were retrieved and assessed for eligibility. Using the inclusion and exclusion criteria as the basis, a total of 41 articles were further excluded. A total of 23 articles were identified and selected for this present study.

Results

A total of 23 studies met the inclusion criteria. These studies were conducted in 9 countries: Canada (*n*=3), Ireland (*n*=1), Kuwait (*n*=1), Malta (*n*=1), Portugal (*n*=2), Scotland (*n*=1), Taiwan (*n*=1), Turkey (*n*=3), and United States (*n*=10). Out of the 23 included studies, seven were experimental design studies, eleven were quasi-experimental design, and five were qualitative research. The total number of participants in this review was 1,929 which are mostly nursing students while a few are from other health care fields. The types of virtual modalities in this review consisted of virtual clinical simulation, virtual simulation training, virtual patient simulator, virtual gaming simulation, virtual reality software, and virtual game-based learning. The studies were further categorized based on Kraiger and colleagues' multidimensional classification of learning outcomes: cognitive, skills-based, and affective[8]. In this study, skills-based outcomes refer to generic or transferable skills (e.g., communication, clinical reasoning, critical thinking) related to the use of virtual simulation. On the other hand, cognitive learning outcomes refer to knowledge acquisition and cognitive strategies associated with the use of virtual simulation. Lastly, affective domains include attitudinal outcomes, self-efficacy, engagement, ease of use, and preference in using virtual simulation. The results were narratively summarized to discuss: 1. the effectiveness of virtual simulation in improving student knowledge; 2. effectiveness of virtual simulation in improving skills; and 3. impact of virtual simulation on student attitude and satisfaction.

Knowledge

Out of twenty-three studies included in this synthesis, eleven studies assessed the effectiveness of virtual simulation on improving the cognitive domain of learning. Two studies examined the effect of virtual simulation on students' level of critical thinking. Kang, et al.[9] found that critical thinking was improved but was not significant before and after virtual simulation. Similarly, Turrise, et al.[10] also found that there are no statistically significant differences in critical thinking between the intervention (virtual simulation) and control (written case studies) groups. Rossler, et al.[11] also concluded that the use of virtual simulation has no statistically significant findings in knowledge for those using traditional programmatic teaching versus the addition of virtual reality simulation (VEST). Furthermore, Giordano, et al.[12] found no difference in knowledge retention towards responding during an opioid-related overdose between students using virtual reality simulation to hybrid simulation. Cobbett, et al.[13] also found no statistically significant difference in student knowledge between students taught face-to-face and those taught with virtual clinical simulations.

Contrary to these studies, Borg Sapiano, et al.[14] found that virtual simulation improves knowledge during patient deterioration. Padilha, et al.[15] also found in their study that the clinical virtual simulation group made more significant improvements in terms of knowledge posttest in both hybrid simulation group and virtual simulation group. Samosorn, et al.[16] and İsmailoğlu, et al.[17] also found statistical significance in the pre- and post-test results in participants knowledge. Similarly, Foronda, et al.[18] found statistically significant improvement in cognitive knowledge related to evidence-based practice.

Skills

Eight studies evaluated the efficacy of virtual simulation in improving the skills of the students. Clinical skills tasks that were examined included learning of wound care[19]; nasogastric tube placement[20]; recognition of intraoperative myocardial infarction[21]; clinical judgment[22]; phlebotomy performance[23]; tracheostomy care[24]; pediatric nursing care[25]; and intravenous catheterization[17].

Two of these studies found a significant difference in skills performance between those who used virtual simulation versus those that used the traditional mode of teaching the content [24,17]. Conversely, one study did a pre- and post-test design and found an increase in their clinical judgment skills after using virtual simulation[22]. Also, two of these studies examined the use of standard patient, low fidelity simulation, and high-fidelity simulation and found that virtual reality simulation is equally effective or even better[23,26]. Two qualitative studies showed an increase in student clinical skills by using virtual simulation as perceived by the study participants[19,25]. Finally, a study by Aebersold, et al.[20] found that the ability to correctly place the NGT by the intervention group was statistically significant compared with the control group.

Affective

Twelve studies focused their inquiry on the effect of virtual simulation in the participants' affective domains of learning. The areas that were examined by these studies include satisfaction with learning experiences[15], level of confidence[13,17], affective knowledge[18], technology use and satisfaction[27,28,29,15,10], and perceived effectiveness[27,21,15,12,30]. All the studies included have overwhelming positive findings with regard to virtual simulation and affective outcome.

Discussion

This review extracted and summarized twenty-three studies that investigated the effectiveness of virtual simulation in nursing education in improving student knowledge, skills, and attitudes. Twenty-two of the studies have been published in nursing journals while

one[15] was published in a medical journal. The studies were conducted in developed countries such as Canada, Ireland, Kuwait, Malta, Portugal, Scotland, Taiwan, Turkey, and United States. The absence of studies using virtual simulation in developing countries for this current synthesis of literature could be due to the high cost of the software and hardware needed for virtual simulation technology. In this review, nine studies focused on the cognitive domain, ten studies that delved on the skills domain, and twelve on the affective domains of learning.

Based on eleven studies that examined the effectiveness of virtual simulation in improving knowledge, five studies showed no significant differences between virtual simulation and their respective control groups. This means that virtual reality simulation was found equally effective compared to the traditional instructional method[9,11], use of case studies[10], hybrid simulation[12], and face-to-face teaching[13]. On the other hand, six studies showed significant differences between virtual simulation and their respective control groups. This purports that virtual reality simulation is more effective than traditional laboratory simulation[27] or without the use of virtual simulation[14,18].

Out of the eight studies that investigated the effect of virtual simulation in the realm of skills, three of these studies found a significant difference in skills performance between those who used virtual simulation versus those that used the traditional mode of teaching the content. Also, two studies showed effectiveness in increasing clinical skills when using virtual simulation. The remaining three of these studies found that virtual simulation is equally effective or even better compared to low fidelity, high fidelity, or standard patient simulations. Thus, all eight studies positively showed improvement in students' clinical skills involving virtual simulation. Similarly, the twelve studies that focused on the impact of virtual simulation on the affective domain of learning of students all showed positive results. Virtual simulation increased students' satisfaction, level of confidence, affective knowledge, and technology use.

There were many variations in the use of virtual simulation in the studies included in this synthesis. This comprises desktop computer simulation[13] and

immersive virtual reality simulation[11]. Future studies should investigate these three specific categories and their impact on the domains of learning. Moreover, there were studies in this synthesis that focused on game-based learning[25,27,29,24]. Because game-based learning is a relatively new approach, there is a need for more research and a more focused study on its effectiveness in nursing education. The study outcomes in this review showed that there is a need for more research studies to be conducted on the effectiveness of virtual simulation in the cognitive domain of learning. There is also a need to conduct studies on how each type of virtual simulation – i.e., desktop computer simulation, immersive virtual reality simulation, and fully immersive virtual simulation environments – affects learning specifically in nursing education. Finally, further research needs to be done on game-based learning and its effect on student learning and nursing education in general.

Limitations of Review

This study only used six online databases which are CINAHL, MEDLINE, PubMed, ERIC, PsychINFO, and ProQuest. There were also no established criteria or standardization for virtual simulation design to be included in the study such as desktop computer simulation, immersive virtual reality simulation, and fully immersive virtual simulation environments. The varied type of virtual simulation design may have impeded the accuracy of the efficacy of virtual simulation in the cognitive, skills, and affective domains of learning. Lastly, the findings and implications of this review may not be generalized to other healthcare professionals as most of the participants were limited to nursing students.

Implications of Findings

This review demonstrates that virtual simulation has overwhelming positive results in increasing the skills and affective performance of students while showing evidence in improving their cognitive domain. Nursing educators, school administrators, policymakers, and other stakeholders need to support future initiatives in the advancement of this technology and its use and possible inclusion in the nursing curriculum.

Conclusions

This review summarized the results of twenty-three studies on the role and effectiveness of virtual simulation on three learning outcomes: knowledge, skills, and affective domains among learners. Studies examining the role of virtual simulation in nursing education show overwhelming evidence supporting a positive impact on student cognitive, skills, and affective, learning outcomes. The establishment and implementation of virtual simulation technology are costly which may be prohibitive in its wider and general use. Future research on the use of virtual simulation is needed to examine the effectiveness of this technology in other health care professions outside of nursing. It might also be valuable to investigate the specific type of virtual simulation (e.g., desktop computer, immersive virtual reality, and fully immersive environment) and its impact on student learning outcomes.

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References

1. Tabatabai S. Simulations and virtual learning supporting clinical education during the COVID 19 pandemic. Adv Med Educ Pract. 2020;11:513–6.

2. COVID-19: SSH/INACSL position Statement on use of Virtual Simulation during the pandemic [Internet]. Ssih.org. [cited 2021 May 15]. Available from: https://www.ssih.org/COVID-19-Updates/ID/2237/COVID-19-SSHINACSL-Position-Statement-on-Use-of-Virtual-Simulation-during-the-Pandemic

3. Baily K. The value of Virtual Reality in healthcare simulation [Internet]. Healthysimulation.com. 2020 [cited 2021 May 15]. Available from: https://www.healthysimulation.com/23811/value-of-vr-healthcare-simulation/

4. Kolb DA. Experiential learning: Experience as the source of learning and development. Vol. 1. Upper Saddle River, NJ: Financial TImes Prentice Hall; 1983.

5. Foronda CL, Fernandez-Burgos M, Nadeau C, Kelley CN, Henry MN. Virtual simulation in nursing education: A systematic review spanning 1996 to 2018: A systematic review spanning 1996 to 2018. Simul Healthc. 2020;15(1):46–54.

6. Woon APN, Mok WQ, Chieng YJS, Zhang HM, Ramos P, Mustadi HB, et al. Effectiveness of virtual reality training in improving knowledge among nursing students: A systematic review, meta-analysis and meta-regression. Nurse Educ Today. 2021;98(104655):104655.

7. Jordan Z, Lockwood C, Munn Z, Aromataris E. The updated Joanna Briggs Institute Model of Evidence-Based Healthcare. Int J Evid Based Healthc. 2019;17(1):58–71.

8. Kraiger K, Ford JK, Salas E. Application of cognitive, skill-based, and affective theories of learning outcomes to new methods of training evaluation. J Appl Psychol. 1993;78(2):311–28.

9. Kang SJ, Hong CM, Lee H. The impact of virtual simulation on critical thinking and self-directed learning ability of nursing students. Clin Simul Nurs. 2020;49:66–72.

10. Turrise SL, Thompson CE, Hepler M. Virtual simulation: Comparing critical thinking and satisfaction in RN-BSN students. Clin Simul Nurs. 2020;46:57–61.

11. Rossler KL, Sankaranarayanan G, Duvall A. Acquisition of fire safety knowledge and skills with virtual reality simulation. Nurse Educ. 2019;44(2):88–92.

12. Giordano NA, Whitney CE, Axson SA, Cassidy K, Rosado E, Hoyt-Brennan AM. A pilot study to compare virtual reality to hybrid simulation for opioid-related overdose and naloxone training. Nurse Educ Today. 2020;88(104365):104365.

13. Cobbett S, Snelgrove-Clarke E. Virtual versus face-to-face clinical simulation in relation to student knowledge, anxiety, and self-confidence in maternal-newborn nursing: A randomized controlled trial. Nurse Educ Today. 2016;45:179–84.

14. Borg Sapiano A, Sammut R, Trapani J. The effectiveness of virtual simulation in improving student nurses' knowledge and performance during patient deterioration: A pre and post test design. Nurse Educ Today. 2018;62:128–33.

15. Padilha JM, Machado PP, Ribeiro A, Ramos J, Costa P. Clinical virtual simulation in nursing education: Randomized controlled trial. J Med Internet Res. 2019;21(3):e11529.

16. Samosorn AB, Gilbert GE, Bauman EB, Khine J, McGonigle D. Teaching airway insertion skills to nursing faculty and students using virtual reality: A pilot study. Clin Simul Nurs. 2020;39:18–26.

17. İsmailoğlu EG, Orkun N, Eşer İ, Zaybak A. Comparison of the effectiveness of the virtual simulator and video-assisted teaching on intravenous catheter insertion skills and self-confidence: A quasi-experimental study. Nurse Educ Today. 2020;95(104596):104596.

18. Foronda CL, Hudson KW, Budhathoki C. Use of virtual simulation to impact nursing students' cognitive and affective knowledge of evidence-based practice. Worldviews Evid Based Nurs. 2017;14(2):168–70.

19. Redmond C, Hardie P, Davies C, Cornally D, Daly O, O'Sullivan C. Increasing competence in wound care: A cross-sectional study to evaluate use of a virtual patient by undergraduate student nurses. Nurse Educ Pract. 2020;44(102774):102774.

20. Aebersold M, Voepel-Lewis T, Cherara L, Weber M, Khouri C, Levine R, et al. Interactive anatomy-augmented virtual simulation training. Clin Simul Nurs. 2018;15:34–41.

21. Chang YM, Lai CL. "Floating heart" application of holographic 3D imaging in nursing education. Int J Nurs Educ. 2018;10(4):25.

22. Fogg N, Kubin L, Wilson CE, Trinka M. Using virtual simulation to develop clinical judgment in undergraduate nursing students. Clin Simul Nurs. 2020;48:55–8.

23. William A, Vidal VL, John P. Traditional instruction versus virtual reality simulation: A comparative study of phlebotomy training among nursing students in Kuwait. J Educ Pr. 2016;7(9):18–25.

24. Bayram SB, Caliskan N. Effect of a game-based virtual reality phone application on tracheostomy care education for nursing students: A randomized controlled trial. Nurse Educ Today. 2019;79:25–31.

25. 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.

26. Erlinger LR, Bartlett A, Perez A. High-fidelity mannequin simulation versus virtual simulation for recognition of critical events by student registered nurse anesthetists. AANA J. 2019;87(2):105–9.

27. Verkuyl M, Romaniuk D, Atack L, Mastrilli P. Virtual gaming simulation for nursing education: An experiment. Clin Simul Nurs. 2017;13(5):238–44.

28. Padilha JM, Machado PP, Ribeiro AL, Ramos JL. Clinical virtual simulation in nursing education. Clin Simul Nurs. 2018;15:13–8.

29. Verkuyl M, Romaniuk D, Mastrilli P. Virtual gaming simulation of a mental health assessment: A usability study. Nurse Educ Pract. 2018;31:83–7.

30. Rose KA, Jenkins SD, Astroth KS, Woith W, Jarvill M. Testing a web-based intervention to improve awareness of civility and incivility in baccalaureate nursing students. Clin Simul Nurs. 2020;48:46–54.