



Full length article

Impact of high-fidelity and virtual simulation experiences on nurses' acquired knowledge and skills for triaging suspected COVID-19 patients



Jefferson Garcia Guerrero^{a,*}, Grace Medalyen Tungpalan-Castro^a, Bara'ah Al Fergani^a,
Nada Hassan Gomma^a, Alaa Hussain Hafiz^b, Minerva Pingue-Raguini^a

^a Fakeeh College for Medical Sciences, Nursing Department, Abdul Wahab Naib Al Haram, Al-Hamra'a, Jeddah, 23323, Saudi Arabia

^b King Abdulaziz University, Faculty of Nursing, PO Box 24828, Jeddah, 21551, Saudi Arabia

ARTICLE INFO

Keywords:

High-Fidelity simulation

Virtual simulation

Acquired knowledge and skills

Professional competence

ABSTRACT

Purpose: This study compares the impact of high-fidelity simulation (HFS) and virtual simulation (VS) experiences on nurses for triaging suspected COVID-19 patients on the basis of their knowledge and skill acquisition.

Background: The essential tools for nurses' professional growth and development are not limited to participation in seminars or symposiums. Training, such as simulation, is also a crucial practice for improving nurses' competency, especially during a pandemic.

Methods: This study employs a comparative research design. The nurses' acquired knowledge and skills are evaluated by dividing them into Groups A and B, which are exposed to HFS and VS, respectively.

Results: The mean scores obtained by both groups in their post-tests are significantly higher than that obtained in their pre-tests, by an average of −18.38 for Group A and 22.14 for Group B. The mean scores obtained in their post-Objective Structured Clinical Examination (OSCE) is significantly higher than that in their pre-OSCE, by an average of −23.00 for Group A and 20.67 for Group B. Moreover, Group B's mean score in the post-test is significantly higher than Group A's by an average of −3.00. Group A's post-OSCE mean score is significantly higher than Group B's by an average of 2.92.

Conclusions: The professional competence of nurses exposed to HFS and VS improves significantly. Nurses exposed to VS acquire more knowledge, whereas nurses exposed to HFS develop higher-level skills.

1. Introduction

Essential tools for the professional growth and development of nurses are not merely limited to participation in seminars or symposiums, where experienced professionals update the former's knowledge base, but also include the facilitation of learning and developing expertise through training and workshops, such as simulations. Additionally, training, such as simulation experience, is crucial for improving nurses' competency in providing safe and precise healthcare. Experienced and knowledgeable nurses are considered optimal in terms of providing excellent healthcare to patients. Nurses dedicated to continuous learning not only strengthen the foundation of healthcare organizations but also generate onward momentum in their professional careers. During this global crisis, nurses worldwide played a crucial role as frontliners in healthcare through their active involvement in assessing and monitoring patients, both suspected and infected with the coronavirus disease 2019 (COVID-19). They

occupied the frontline of medical response despite the constant threat of exposure to infection, which necessitated significant protective and preventive measures against the virus. Therefore, nurses must be trained in triage protocols and adequately equipped with respect to knowledge, skills, and equipment for combating the threat of infection while fulfilling their healthcare obligations.

Simulations develop knowledge and skills in a safe environment, thus allowing participants to repeatedly practice complex skills in well-designed clinical scenarios (Gebreheat et al., 2022). High-fidelity simulation (HFS)—as a modern teaching strategy—is being utilized in the clinical setting as groundwork for nurses in complicated healthcare environments, as it facilitates their learning and preparation for providing effective healthcare (Founds et al., 2011; Galloway, 2009; Williams & Spurlock, 2019). Additionally, an evidence-based exploration assessing HFS' effectiveness for knowledge and professional skills has been found necessary (Lei et al., 2022). However, previous studies have reported

* Corresponding author.

E-mail addresses: jgguerrero@fcms.edu.sa (J.G. Guerrero), gmcastro@fcms.edu.sa (G.M. Tungpalan-Castro), belfergani@fcms.edu.sa (B. Al Fergani), ngomma@fcms.edu.sa (N.H. Gomma), ahhafidh@kau.edu.sa (A.H. Hafiz), mpraguini@fcms.edu.sa (M. Pingue-Raguini).

<https://doi.org/10.1016/j.cexr.2022.100002>

Received 2 August 2022; Received in revised form 6 November 2022; Accepted 7 November 2022

2949-6780/© 2022 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

limited significant differences between an HFS group's and a traditional teaching group's experiences pertaining to knowledge and skills (Jørgensen et al., 2018; Mert Karadas & Terzioğlu, 2019). Alternatively, the use of virtual simulation (VS) positively impacts participants' knowledge and skill acquisition. Furthermore, Chang et al. (2021) reported that the experimental group exposed to VS exhibited significantly higher knowledge scores and better skill performance. However, the finding requires further clarification and exploration through experimental studies and meta-analyses of all available evidence (Chang et al., 2021). The VS technology enables participants to efficiently utilize and improve their skills for critical decision-making, problem-solving, and effective communication (McGaghie et al., 2010; Padilha, 2019). Nevertheless, its impact on participants' knowledge, skills, and confidence requires further evaluation (Gebreheat et al., 2022). Additionally, Cobbett and Snelgrove-Clarke (2016) argued that VS does not induce any difference in students' knowledge acquisition compared to face-to-face simulation.

Previous studies have revealed that repeated simulation experiences improve technical and critical thinking skills (Abe et al., 2013; Adib-Hajbaghery & Sharifi, 2017). Advocates of simulation experience, therefore, highlight the significance of this learning approach for developing nurses' critical thinking skills and healthcare proficiency (Shinnick & Woo, 2013).

Simulation training has been utilized as a large-scale approach to enhance the quality of healthcare delivery. However, its impact on registered nurses is yet to be well-established (Hegland et al., 2017). Jung Kang et al. (2020) suggested the need for a more in-depth exploration to determine whether VS enhances nurses' critical thinking and clinical expertise. Simulation-based training supplements the development of nurses' proficiency. Its elements are considered a well-planned strategy to support the improvement of healthcare quality and minimize medical errors. However, quality randomized controlled trials are reliable determinants of the efficiency of simulation methods and institutions (Hegland et al., 2017). Additionally, Chen et al.'s (2020) study, published in a journal with significant influence in the educational technology research community highlighted the need for conducting structural topic modeling-based analysis of computers and education to identify major research topics and the future directions of technology and education (Chen et al., 2020).

This research was conducted in partnership with the nursing education department of Dr. Soliman Fakeeh Hospital (DSFH), nursing department of Fakeeh College for Medical Sciences (FCMS), and staff of the Clinical Skills and Simulation Center (CSSC). Determining additional support to enhance nurses' expertise, especially in fighting the battle against a deadly virus that continues exerting a global impact, is not only necessary but also urgent. This study compares the impact of nurses' HFS and VS experiences in triaging suspected COVID-19 patients based on their knowledge and skill acquisition. Furthermore, this study investigates the following specific research questions: a) What is the impact of HFS and VS experiences on nurses' pre- and post-test scores? b) What is the impact of HFS and VS experiences on nurses' pre- and post-Objective Structured Clinical Examination (OSCE) scores? c) Is there a significant difference in the post-test and post-OSCE results of the groups of nurses exposed to HFS and VS?

2. Methods

This study utilized a comparative research design to compare the impacts of HFS and VS on nurses' acquired knowledge and skills for triaging suspected COVID-19 patients. One group was exposed to HFS, while the other was exposed to VS.

The participants included bedside nurses working in various units/areas of the hospital—including emergency rooms, intensive care units, neonatal intensive care units, coronary care units, medical-surgical units, telemetry units, operating rooms, delivery rooms, hematology, renal dialysis units, endoscopy units, and oncology units. They possessed a

bachelor's degree in nursing and a license to practice in Saudi Arabia as nurse specialists, and were employed at the DSFH in Jeddah, Saudi Arabia. They had served at patients' bedsides from August 2019 to August 2021 and had no simulation experience. Of the total 256 nurses employed at the DSFH, the researcher randomly selected 60 nurses for Group A (for exposure to HFS) and another 60 for Group B (for exposure to VS). The random selection process was performed by writing the nurses' employee numbers on a sheet of paper and, then, selecting through a process similar to a lottery. The groups comprised male and female participants ranging from 27 to 48 years, and both Saudi and non-Saudi nationals.

The HFS session was administered at the medical-surgical simulation laboratory of the CSSC, using a CAE Apollo simulator and CAE LearningSpace, to record and document the participants' performances. The sessions were divided into three phases: pre-briefing, simulation, and debriefing. Conversely, the VS session was performed in the team-based learning hall of the FCMS, wherein the participants used the Body Interact multiplayer software on the institution's iPads. The sessions were divided into three phases: virtual pre-briefing, virtual simulation, and virtual debriefing.

Both sessions utilized the same scenario: "Triaging Suspected COVID-19 Patients." The study was conducted from August 15 to 19, 2021, and catered to 24 participants per day; 12 participants attended the HFS and VS each. The participants were mixed with other nurses who participated in the session. To evaluate their professional competence, a pre/post-test and pre/post-OSCE were conducted. The test questions used in the pre/post-test and the checklist utilized in the pre/post-OSCE were prepared by the authors. The checklist was sent along with the simulation scenario to the nurse educators at the DSFH, and senior faculty members in the nursing department of the FCMS, to ensure the content's validity and accuracy.

All participants took a pre-test and post-test before and after the sessions, respectively, which assessed their acquired knowledge. All the test questions were case-based (NCLEX-type questions), related to every scenario, and required a high level of critical thinking. All the items comprised 10 multiple-choice questions (MCQs), with five choices and one point for each. Additionally, there were five open-ended essay questions, with five points each; thus, the total was 25 points. A pilot test for the pre/post-tests was conducted with 10 nurses to ensure that the exam did not exceed 30 min and that each question was accepted for its difficulty index. The test was overseen by a computer-based exam software called *Speedwell*, which automatically calculated and generated the pre- and post-test results. Item analysis was performed: four moderate MCQs, three difficult MCQs, three hard MCQs, three moderate essay questions, one difficult essay question, and one hard essay question. The pre- and post-test reliability were tested using Cronbach's alpha, which was 0.86, indicating very good reliability.

The OSCE was also executed before and after the simulation sessions to assess the nurses' acquired skills. In the OSCE, the rubrics used a 4-point Likert scale comprising 3 (performed correctly), 2 (performed incompletely), 1 (performed incorrectly), and 0 (not performed). The OSCE checklist was based on the procedures performed in every scenario. The nurses and raters were informed of their specific roles and tasks in the OSCE. The raters included FCMS's nursing faculty members and DSFH's clinical preceptors. The pre- and post-OSCE checklist underwent a pilot test with 10 nurses, and the reliability was tested using kappa coefficients, with a result of 0.91, implying an almost perfect agreement. The OSCE checklist was also encoded in the institutions' *Speedwell* systems. Additionally, facilitators of both simulation sessions and invigilators of the pre- and post-tests were unaware of who was included in and excluded from the study.

Laboratory rooms were set up, and all necessary equipment for the procedure and scenario was posted outside the OSCE station rooms. The organizer, who acted as a facilitator and timekeeper during the OSCE, ensured that the nurses remained inside the classrooms and permitted to leave only when taking the laboratory-based examination. Additionally,

mobile phones and other devices were prohibited inside the classroom.

During the OSCE, the nurses were provided 1 min to read and analyze the scene before entering the rooms. As soon as the examinee entered the room, a 5-min time period began. Two raters were assigned to each OSCE station; they used the same rubric.

The results of the OSCE pre- and post-tests were summed up for data assessment. The collected data were encoded and analyzed using the statistical package Stata 15.1, and their means and standard deviations (SDs) were used to summarize the data. The *t*-test was performed to compare the results of the pre-test, post-test, and OSCE results of both groups.

Ethical considerations

The study's purpose, including the nurses' right to withdraw, was explained to them. Written consent, with specified information, was provided by the participants before the study commenced. Ethical approval was obtained from the affiliated institutional review board (284/IRB/2022).

3. Results

Table 1 presents the pre- and post-test results of the two groups of staff nurses (Group A with HFS exposure and Group B with VS exposure). The mean pre-test score of Group A with HFS exposure was 73.91, with an SD of 8.22, and the mean post-test score was 92.29, with an SD of 4.97; this is significantly higher, with an average difference of -18.38 , supported by a *p*-value of 0.00. The mean pre-test score of Group B with VS exposure was 73.14, with an SD of 10.40, and the mean post-test score was 95.29, with an SD of 4.96; this, too, is significantly higher, with an average difference of -22.14 , supported by a *p*-value of 0.00 (see Table 1).

Table 2 presents the pre- and post-OSCE results of the two groups of staff nurses (Group A with HFS exposure and Group B with VS exposure). The mean pre-test score of Group A with HFS exposure was 73.08, with an SD of 5.26, and the mean post-test score was 96.08, with an SD of 4.15; this is significantly higher, with an average difference of -23.00 , supported by a *p*-value of 0.00. The mean pre-test score of Group B with VS exposure was 72.50, with an SD of 5.21, and the mean post-test score was 93.17, with an SD of 4.01; this, too, is significantly higher with an average difference of -20.67 , supported by a *p*-value of 0.00 (see Table 2).

Table 3 presents the post-test and post-OSCE results of the two groups of staff nurses (Group A with HFS exposure and Group B with VS exposure). In the post-test, the mean score of Group A with HFS exposure was 92.29, with an SD of 4.97, and the mean score of Group B with VS exposure was 95.29, with an SD of 4.96; this is higher than that of the other group, with an average difference of -3.00 , supported by a *p*-value of 0.001. Conversely, in the post-OSCE group, the mean score of Group A with HFS exposure was 96.08, with an SD of 4.15, and the mean score of Group B with VS exposure was 93.17, with an SD of 4.96; this is lower than that of the other group, with an average difference of 2.92, supported by a *p*-value of 0.00 (see Table 3).

Table 1

Comparison of the Pre- and Post-Test Scores of Group A with HFS and Group B with VS exposure.

Group	Test	Mean	SD	Mean Difference	<i>p</i> -value	Difference
Group A with HFS	Pre	73.91	8.22	-18.38	0.00	Significant
	Post	92.29	4.97			
Group B with VS	Pre	73.14	10.40	-22.14	0.00	Significant
	Post	95.29	4.96			

Table 2

Comparison of the Pre- and Post-OSCE results of Group A with HFS and Group B with VS.

Group	Test	Mean	SD	Mean Difference	<i>p</i> -value	Difference
Group A with HFS	Pre	73.08	5.26	-23.00	0.00	Significant
	Post	96.08	4.15			
Group B with VS	Pre	72.50	5.21	-20.67	0.00	Significant
	Post	93.17	4.01			

Table 3

Comparison of the Post-test and Post-OSCE results of Group A with HFS and Group B with VS.

Assessment	Group	Mean	SD	Mean Difference	<i>p</i> -value	Difference
Post-test	Group A with HFS	92.29	4.97	-3.00	0.001	Significant
	Group B with VS	95.29	4.96			
Post OSCE	Group A with HFS	96.08	4.15	2.92	0.00	Significant
	Group B with VS	93.17	4.01			

4. Discussions

This study compared the impact of nurses' HFS and VS experiences for triaging suspected COVID-19 patients on the basis of their knowledge and skill acquisition. Furthermore, the post-test and post-OSCE scores of both groups that underwent HFS and VS exposure showed significant improvements compared to their pre-test and pre-OSCE scores. This implies that the nurses acquired and developed professional competence through high-level knowledge and skills acquired from simulation exposure. Interestingly, nurses exposed to VS acquired more knowledge, and those exposed to HFS developed higher-level skills.

The benefits of simulation-based training for proficiency and clinical practice expertise depend on the simulation program's influence and strategy, as well as the nurse's metacognitive management of medical affairs in their academic and clinical practices (Guerrero et al., 2021; Nash & Harvey, 2017). Thus, participation in a simulation program improves registered nurses' knowledge (Bliss & Aitken, 2018; Disher et al., 2014), improves critical thinking and learning retention (Guerrero, Ali, & Attallah, 2022), and advances expertise in the field (Guerrero et al., 2021). Owing to its positive outcomes, simulation-based practices are deemed an efficient process for enhancing nurses' competency through healthcare training (Hegland et al., 2017).

The use of HFS is a key strategy for enhancing knowledge and skill acquisition, including improving the quality and safety of clinical practice (Batista et al., 2014; Heimann et al., 2013; Kneebone, 2005; Lapkin et al., 2010; McGaghie, 2010; Meakim et al., 2013; Padilha, 2019; Pinar et al., 2015; Yuan et al., 2012). Moreover, HFS scenario exposure boosts learning retention and improves practical skills in performing nursing procedures that can be applied in the real world (Guerrero, Ali, & Attallah, 2022). However, according to Lawrence et al. (2018) the specific aspect of HFS is developing skills such as noticing patient problems, appropriate response, and reflect on patient care experiences and Zhen et al. (2021) reported that HFS exposure train the participant's clinical skills on how to recognize appropriate actions to solve clinical problems.

VS on the other hand is an instructional strategy that builds a virtual educational environment that supports the development of clinical competencies (Padilha et al., 2019) and an effective and engaging learning tool (Verkuyt & Hughes, 2019). VS may also contribute to reducing clinical mistakes and making improvements for safer healthcare delivery (Berman et al., 2016). Additionally, a virtual learning setting offers an immersive experience through engagement with HFS in real-life

scenarios created in the simulation laboratory (Aebersold et al., 2012; Gordon & McGonigle, 2018; Youngblood et al., 2008). The high level of realism and an authentic storyline in this virtual gaming simulation contributed to the learning experience and enhanced knowledge, engagement, and self-confidence (Verkuyl & Hughes, 2019). It is a vital strategy for improving knowledge in identifying and responding to patient conditions (Goldsworthy et al., 2022) and providing opportunities for the practice of non-technical skills (Tschannen et al., 2012). Moreover, VS exhibits the potential to support learners' independent knowledge development, critical thinking, and problem-solving (Allaire, 2015; Sunnvqvist et al., 2016). Interestingly, in a recent study by Park et al. (2022), when investigating the effects of each simulation modality (HFS vs. VS), the group of participants who were exposed to VS scored significantly higher on clinical reasoning and problem-solving processes than those in the HFS group.

Shin et al.'s (2015) meta-analysis of 20 studies on the utilization of HFS in nursing education revealed that HFS could improve learning outcomes in terms of knowledge and skills, with a medium-to-large effect size, compared to traditional clinical teaching. Furthermore, this is consistent with the finding of Chang et al. (2021) that the experimental group that experienced VS scored significantly higher on knowledge and skill performance than the control group. However, previous findings are contrary to the current study's results, demonstrating that the knowledge and skill acquired through simulation experience depend on modality (Allaire, 2015; Sunnvqvist et al., 2016).

4.1. Study limitations

The study was conducted in one setting/location, though the sample size was large. Furthermore, it evaluated only one scenario. Additional studies in multiple settings/locations with different participant traits are necessary to strengthen the present study's claims.

4.2. Implications

Simulation is a recognized technique for improving patient safety. Therefore, a combination of a well-structured HFS and VS for nurses' professional development might be useful to improve their knowledge and skills, thus enhancing their professional competence and confidence in practice.

5. Conclusions

Simulation of different modalities is an alternative or complementary strategy for experiencing and practicing various clinical situations in a safe environment that do not harm the patient. Moreover, simulation played a significant role in equipping our institution's nursing workforce with appropriate proficiency in responding to the COVID-19 pandemic. This method of professional development might help improve nurses' knowledge and skills, thereby enhancing their professional competence, independence, and confidence in practice. However, an appropriate simulation modality and a well-structured scenario—conducted by a trained simulation facilitator in a well-equipped simulation environment—play crucial roles in achieving the goals of simulation. Moreover, combining both simulation modalities (HFS and VS) delivers a significant advantage for participants' acquisition of knowledge and skills.

Recommendations

The researchers recommend combining the HFS and VS for the regular professional development of nurses working at patients' bedsides, to further nurture, enhance, and advance their knowledge and skills in dealing with patients, especially in the context of the COVID-19 pandemic. Using a standardized simulation process model and selecting the optimal debriefing model are also necessary to achieve a positive outcome.

Hospital nurse educators should be trained to conduct a structured simulation of nurses through pre-briefing, simulation, and debriefing. Hospitals should invest in establishing simulation centers with HFS and in adopting VS for nurses and other healthcare practitioners' professional development training.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest

The authors declare no conflict of interest.

Acknowledgments

The researchers express their gratitude for the support from staff nurses and educators of the Dr. Soliman Fakeeh Hospital, and the faculty members and clinical instructors of the Fakeeh College for Medical Sciences, Nursing Department. We sincerely thank all the observers and raters who participated in the pre- and post-tests and the objective structured clinical examinations.

References

- Abe, Y., Kawahara, C., Yamashina, A., & Tsuboi, R. (2013). Repeated scenario simulation to improve competency in critical care: A new approach for nursing education. *American Journal of Critical Care*, 22(1), 33–40. <https://doi.org/10.4037/ajcc2013229>
- Adib-Hajbaghery, M., & Sharifi, N. (2017). Effect of simulation training on the development of nurses and nursing students' critical thinking: A systematic literature review, 2017 *Nurse Education Today*, 50, 17–24. <https://doi.org/10.1016/j.nedt.2016.12.011>
- Aebersold, M., Tschannen, D., Stephens, M., Anderson, P., & Lei, X. (2012). Second life: A new strategy in educating nursing students. *Clinical Simulation in Nursing*, 8(9), e469–e475. <https://doi.org/10.1016/j.jecns.2011.05.002>
- Allaire, J. L. (2015). Assessing critical thinking outcomes of dental hygiene students utilizing virtual patient simulation: A mixed methods study. *Journal of Dental Education*, 79(9), 1082–1092.
- Batista, R., Martins, J., Pereira, M., & Mazzo, A. (2014). High-fidelity simulation in the Nursing degree: Gains perceived by students. *Revista de Enfermagem Referência*, 4(1), 135–144. <https://doi.org/10.12707/RH113169>
- Berman, N. B., Durning, S. J., Fischer, M. R., Huwendiek, S., & Triola, M. M. (2016). The role for virtual patients in the future of medical education. *Academic Medicine*, 91(9), 1217–1222. <https://doi.org/10.1097/ACM.0000000000001146>
- Bliss, M., & Aitken, L. M. (2018). Does simulation enhance nurses' ability to assess deteriorating patients? *Nurse Education in Practice*, 28, 20–26.
- Chang, H. Y., Wu, H. F., Chang, Y. C., Tseng, Y. S., & Wang, Y. C. (2021). The effects of a virtual simulation-based, mobile technology application on nursing students' learning achievement and cognitive load: Randomized controlled trial. *International Journal of Nursing Studies*, 120, Article 103948.
- Chen, X., Zou, D., Cheng, G., & Xie, H. (2020). Detecting latent topics and trends in educational technologies over four decades using structural topic modeling: A retrospective of all volumes of computers & education. *Computers & Education*, 151, Article 103855.
- Cobbett, S., & Snelgrove-Clarke, E. (2016). 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 Education Today*, 45, 179–184.
- Disher, J., Burgum, A., Desai, A., Fallon, C., Hart, P. L., & Aduddell, K. (2014). The effect of unit-based simulation on nurses' identification of deteriorating patients. *Journal for Nurses in Professional Development*, 30(1), 21–28.
- Found, S. A., Zewe, G., & Scheuer, L. A. (2011). Development of high-fidelity simulated clinical experiences for baccalaureate nursing students. *Journal of Professional Nursing*, 27(1), 5–9.
- Galloway, S. (2009). Simulation techniques to bridge the gap between novice and competent healthcare professionals. *Online Journal of Issues in Nursing*, 14(2). <http://www.nursingworld.org/MainMenuCategories/ANAMarketplace/ANAPeriodicals/OJIN/TableofContents/Vol42009/No2May09/Simulation-Techniques.html>
- Gebreheath, G., Whitehorn, L. J., & Paterson, R. E. (2022). Effectiveness of digital simulation on student nurses' knowledge and confidence: An integrative literature review. *Advances in Medical Education and Practice*, 13, 765.
- Goldsworthy, S., Muir, N., Baron, S., Button, D., Goodhand, K., Hunter, S., ... Peachey, L. (2022). The impact of virtual simulation on the recognition and response to the rapidly deteriorating patient among undergraduate nursing students. *Nurse Education Today*, 110, Article 105264. <https://doi.org/10.1016/j.nedt.2021.105264>
- Gordon, R. M., & McGonigle, D. (2018). *Virtual simulation in nursing education*. Springer Publishing Company, LLC, ISBN 978-0-8261-6963-1.

- Guerrero, J. G., Ali, S. A. A., & Attallah, D. M. (2022a). The acquired critical thinking skills, satisfaction, and self confidence of nursing students and staff nurses through high-fidelity simulation experience. *Clinical Simulation in Nursing*, 64, 24–30. <https://doi.org/10.1016/j.ecns.2021.11.008>
- Guerrero, J. G., Hafiz, A. H., Eltohamy, N. A. E., Gomma, N., & Jarrah, I. A. (2021). Repeated exposure to high-fidelity simulation and nursing interns' clinical performance: Impact on practice readiness. *Clinical Simulation in Nursing*, 60, 18–24. <https://doi.org/10.1016/j.ecns.2021.06.011>
- Guerrero, J. G., Rosales, N. S., & Castro, G. M. T. (2022b). Impact of high-fidelity simulation exposure of nursing students with their objective structured clinical examination: A quasi-experimental study, 00 *Nursing Open*, 1–8. <https://doi.org/10.1002/nop2.1343>
- Hegland, P. A., Aarlie, H., Strømme, H., & Jamtvedt, G. (2017). Simulation-based training for nurses: Systematic review and meta-analysis. *Nurse Education Today*, 54, 6–20. <https://doi.org/10.1016/j.nedt.2017.04.004>
- Heimann, C., Prado, C., de Moraes, R. R., Vidal, G., Liberal, D., Oliveira, G., & Barata, M. (2013). Acquiring nursing knowledge through the constructivist method. *Revista da Escola de Enfermagem da USP*, 47(4), 997–1000. <https://doi.org/10.1590/S0080-623420130000400032>
- Jørgensen, B. E., Larsen, M., & Gram, B. (2018). Simulation as an educational tool in acute nursing care: A controlled intervention study. *Nurse Education in Practice*, 32, 28–33.
- Jung Kang, S., Min Hong, C., & Lee, H. (2020). The impact of virtual simulation on critical thinking and self-directed learning ability of nursing students. *Clinical Simulation in Nursing*, 49, 66–72.
- Kneebone, R. (2005). Evaluating clinical simulations for learning procedural skills: A theory-based approach. *Academic Medicine*, 80(6), 549–553. <https://doi.org/10.1097/00001888-200506000-00006>
- Lapkin, S., Fernandez, R., Levett-Jones, T., & Bellchambers, H. (2010). The effectiveness of using human patient simulation manikins in the teaching of clinical reasoning skills to undergraduate nursing students: A systematic review. *JBI Library of Systematic Reviews*, 8(16), 661–694. <https://doi.org/10.1016/j.ecns.2010.05.005>
- Lawrence, K., Messias, D. K. H., & Cason, M. L. (2018). The influence of simulation experiences on new nurses' clinical judgment. *Clinical Simulation in Nursing*, 25, 22–27. <https://doi.org/10.1016/j.ecns.2018.10.008>
- Lei, Y. Y., Zhu, L., Sa, Y. T. R., & Cui, X. S. (2022). Effects of high-fidelity simulation teaching on nursing students' knowledge, professional skills and clinical ability: A meta-analysis and systematic review. *Nurse Education in Practice*, Article 103306.
- McGaghie, W. C., Issenberg, S. B., Petrusa, E. R., & Scalese, R. J. (2010). A critical review of simulation-based medical education research: 2003–2009. *Medical Education*, 44(1), 50–63. <https://doi.org/10.1111/j.1365-2923.2009.03547.x>
- Meakim, C., Boese, T., Decker, S., Franklin, A. E., Gloe, D., Lioce, L., Sando, C. R., & Borum, J. C. (2013). Standards of best practice: Simulation standard I: Terminology. *Clinical Simulation in Nursing*, 9(6). <https://doi.org/10.1016/j.ecns.2013.04.001>. S3–S11.
- Mert Karadas, M., & Terzioğlu, F. (2019). The impact of the using high-fidelity simulation and standardized patients to management of postpartum hemorrhage in undergraduate nursing students: A randomized controlled study in Turkey. *Health Care for Women International*, 40(5), 597–612.
- Nehring, W. M., & Lashley, W. (2004). Current use and options regarding human patient simulators in nursing education: An international survey. *Nursing Education Perspectives*, 25(5), 244–248.
- Padilha, J. M., Machado, P. P., Ribeiro, A., Ramos, J., & Costa, P. (2019). Clinical virtual simulation in nursing education: Randomized controlled trial. *Journal of Medical Internet Research*, 21(3), Article e11529. <https://doi.org/10.2196/11529>
- Park, S., Hur, H. K., & Chung, C. (2022). Learning effects of virtual versus high-fidelity simulations in nursing students: A crossover comparison. *BMC Nursing*, 21(1), 1–9.
- Pinar, G., Knight, C., Gaiosio, V., Watts, P., Dailey, K., Britt, S., Catron, K., & Zengul, F. (2015). The effects of high fidelity simulation on nursing students' perceptions and self-efficacy of obstetric skills. *International Archives of Nursing and Health Care*, 1(1), 1–7. <https://doi.org/10.23937/2469-5823/1510008>
- Shin, H., Ma, H., Park, J., Ji, E. S., & Kim, D. H. (2015). The effect of simulation courseware on critical thinking in undergraduate nursing students: Multisite pre-post study. *Nursing Education Today*, 35(4), 537–542.
- Shinnick, M. A., & Woo, M. A. (2013). The effect of human patient simulation on critical thinking and its predictors in prelicensure nursing students. *Nurse Education Today*, 1062–1067.
- Sunnqvist, C., Karlsson, K., Lindell, L., & Fors, U. (2016). Virtual patient simulation in psychiatric care—a pilot study of digital support for collaborate learning. *Nurse Education in Practice*, 17, 30–35.
- Tschannen, D., Aebersold, M., McLaughlin, E., Bowen, J., & Fairchild, J. (2012). Use of virtual simulations for improving knowledge transfer among baccalaureate nursing students. *Journal of Nursing Education and Practice*, 2(3), 15. <https://doi.org/10.5430/jnep.v2n3p15>
- Verkuyll, M., & Hughes, M. (2019). Virtual gaming simulation in nursing education: A mixed-methods study. *Clinical Simulation in Nursing*, 29, 9–14. <https://doi.org/10.1016/j.ecns.2019.02.001>
- Williams, T., & Spurllock, W. (2019). Using high fidelity simulation to prepare baccalaureate nursing students enrolled in a historically black college and university. *The Journal of the Association of Black Nursing Faculty in Higher Education*.
- Youngblood, P., Harter, P. M., Srivastava, S., Moffett, S., Heinrichs, W. L., & Dev, P. (2008). Design, development, and evaluation of an online virtual emergency department for training trauma teams. *Simulation in Healthcare*, 3(3), 146–153. <https://doi.org/10.1097/SIH.0b013e31817bedf7>
- Yuan, H. B., Williams, B. A., & Fang, J. B. (2012). The contribution of high-fidelity simulation to nursing students' confidence and competence: A systematic review. *International Nursing Review*, 59(1), 26–33. <https://doi.org/10.1111/j.1466-7657.2011.00964.x>
- Zhen, L. I., Huang, F. F., Shiah-Lian, C. H. E. N., Anni, W. A. N. G., & Yufang, G. U. O. (2021). The learning effectiveness of high-fidelity simulation teaching among Chinese nursing students: A mixed-methods study. *Journal of Nursing Research*, 29(2), e141. <https://doi.org/10.1097/JNR.0000000000000418>