JNPD Journal for Nurses in Professional Development • Volume 40, Number 2, 75–81 • Copyright © 2024 Wolters Kluwer Health, Inc. All rights reserved.

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Effect of a Virtual Reality Simulation Modality on Registered Nurse Knowledge and Behavior Related to *Clostridioides difficile* Prevention

An Experimental, Cluster Randomized Controlled Trial

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Virtual reality simulation (VRS) has emerged as an educational methodology in nursing professional development. A cluster randomized controlled trial was conducted with a sample of clinical registered nurses to compare effectiveness of VRS and traditional education on knowledge and behavior related to *Clostridioides difficile* prevention. No significant differences were found in the effectiveness of the two modalities, suggesting the usefulness of VRS as a teaching methodology.

Effective educational delivery requires nursing professional development (NPD) practitioners to engage registered nurses (RNs) to address rising health care-associated infections. Behavior change must result from educational activities to prevent hospital-acquired infections. Reality is the world we live in and experience with our senses. Virtual reality (VR) is defined as a three dimensional (3D) computer-generated learning environment based on presence and immersion, and it encompasses several modalities (Lioce et al., 2020). VR can range from 3-D head-mounted displays to screen-based multi-media environments with simulation, known as virtual reality simulation (VRS) (Kyaw et al., 2019; Lioce et al., 2020; Lohre et al., 2020; Society for Simulation in Healthcare, 2020). VR platforms resemble the practice environment to facilitate application of learning in healthcare settings (Society for Simulation in Healthcare, 2020). Advances in VR technologies, such as holograph and lithograph optical displays, create realness and immersion within these learning modalities (Xiong et al., 2021).

VR platforms allow learners to interact with virtual patients as they would in the real practice setting. Technology enhancements with interactive 360 video systems and VR simulators offer visualization of tasks, videos, and simulations where learners can perform tasks in the virtual environment based on course objectives (Izard et al., 2018). VRS can use keyboards, mouse, speech and/or voice recognition devices, motion sensors, and haptics (Society for Simulation in Healthcare, 2020). This method is cost-effective and offers repetition and training on-demand (Society for Simulation in Healthcare, 2020). VR software and hardware costs for headsets and computer setup or scenarios range from $3,000 to $15,000. Additional operational costs are determined by the number of users (Pottle, 2019).

Conversely, traditional education often uses passive approaches, such as synchronous, real-time lectures in a classroom or laboratory setting or asynchronous, learner-paced content accessible online (Ramirez, 2018). These methods might fail to engage learners (Lohre et al., 2020). In addition, they can require time away from the patient care unit with little opportunity to revisit content or practice skills.

A focus of education in health care has been *Clostridioides difficile* (CDI), a bacterium germ that can cause diarrhea. The incidence of CDI in the United States is 121.2 cases per 100,000 persons (Centers for Disease Control and Prevention, 2019). CDI-related costs per case are estimated to be between $11,000 and $17,260 (Scott et al., 2019). CDI preventative measures in healthcare settings include avoiding unnecessary use of antibiotics, hand hygiene, contact precautions, and thorough high-touch environmental cleaning (Nielsen et al., 2019). Educational interventions that address knowledge

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The authors have disclosed that they have no significant relationship with, or financial interest in, any commercial companies pertaining to this article.

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

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DOI: 10.1097/NND.0000000000001031

and behavior gaps of healthcare workers in these areas have the potential (Finnimore et al., 2023) to reduce CDI incidence by 35%–50% (Kamkar, 2017; Read et al., 2020). Patient outcome data at the study site illustrated that multiple units were underperforming when compared to the standardized infection ratio for CDI and traditional educational approaches were not filling the professional practice gaps identified by nursing.

Positive learning outcomes have been demonstrated with VR use (Joda et al., 2019; Kyaw et al., 2019; Lohre et al., 2020; ONeill et al., 2018; Yu & Mann, 2021), compared to traditional approaches (Bakhos et al., 2020; Berg & Steinsbekk, 2020; Marei et al., 2017). However, these studies were limited by low-level evaluation, such as participant satisfaction, and lacked theoretical frameworks. Despite multiple studies with students, minimal evidence exists about use of VR or screen-based simulation with practicing healthcare professionals (Berg & Steinsbekk, 2020; Kang et al., 2020; Padilha et al., 2019; Tran et al., 2020). VR intervention studies are needed that have a theoretical basis and evaluation of behavior change and impact for greater applicability in practice.

Purpose/Aims

The purpose of this study was to compare the effectiveness of VRS with traditional education in improving RN knowledge and behavior related to *C. difficile* prevention. Hypotheses were that VRS would result in greater (a) knowledge gain than traditional education and (b) behavior change than traditional education. In addition, the relationship of selected demographic and professional characteristics on knowledge and behavior change was explored.

Conceptual frameworks

The NPD practice model framed the structures and processes of this study (Harper & Maloney, 2022). Inputs are the learner and NPD practitioner, throughputs are processes that transform the inputs, and outputs are the products exported into the environment, which include learning, change, and professional role competence and growth. Learning is described as the acquisition of knowledge, skills, abilities, and judgment that leads to practice change.

Kolb's experiential learning theory cycle was used in the educational design of this study. Kolb (2014) defines learning as a process in which knowledge is created through the transformation of experience. This theory consists of four learning stages. Concrete experience is the stage in which the learner participates in a new experience. The reflective observation stage occurs when the learner reflects on the experience. In the abstract conceptualization stage, the learner assigns meaning to the learning experience. Finally, in the active experimentation stage, the learner applies what was learned, completing the learning cycle.

METHODS

Design

A cluster randomized controlled trial with two groups (Campbell et al., 2012) was used to compare the effect of VRS to traditional education on RN knowledge and behavior. The sample pool consisted of RNs from six adult acute care units, paired based on patient index severity. One pair of two units was randomly selected and then randomly allocated by unit to receive the VRS intervention or control. Screen-based VRS, accessible within the health system learning management system (LMS), was used. The independent variables were the educational modalities. Demographics and setting were included as covariates. Dependent variables were RN knowledge and behavior change. The intervention group participated in a VRS educational intervention designed based on Kolb's experiential learning (Kolb, 2014) cycle through concrete participation in the VRS, reflection in the learning platform, abstract conceptualization relevance of the VRS content, and active experimentation testing of knowledge and skill application (Poore et al., 2014). The control group participated in traditional education, consisting of an asynchronous learning module.

Power Analysis

Sample size was calculated for 80% power and 5% Type I error to detect a standardized moderate effect size of 0.5 or larger between intervention and control groups (Kang et al., 2020; Padilha et al., 2019; Shin et al., 2019) and yielded 41 for each group based on Statacorp 17.

Setting and Participants

This study was conducted in a large multisite, Magnet-designated hospital system with approximately 4,400 RNs in the nursing workforce, with an average of 60 RNs per inpatient unit. Participants included RNs from the randomly selected and assigned units.

Recruitment and Study Procedures

Inclusion criteria for RNs included full-time status and ability to complete the study protocol. RNs on leave of absence or vacation during the pretest, intervention, or posttests were excluded. Resource and float nurses were excluded because of multiple unit exposure and interaction with the invention and control units.

Eligible participants were identified through the LMS and unit leadership. Participants received an e-mail link to login to the LMS and access the study purpose, the informed consent, and directions to complete the education and testing. Participation was also encouraged during staff huddles. In addition, unit leaders were encouraged to allow adequate time to complete the education and study requirements. The study was approved by the institutional review board.

Data Collection/Instruments

Participants were allowed 30 days to complete the education. See Table 1 for details on times and groups. Both VRS and traditional education programs required approximately 1 hour to complete; however, participants were allowed to spend as much time as they wanted covering the materials. In addition to demographic information, a 10-item multiple-choice, researcher-developed knowledge assessment was administered and scored on a scale of 0–10 in the LMS. Equivalent formats were used for each group, with different pre- and posttest versions. Tools were tested with a small group of 10 clinical nurses, and content validity was tested by four subject matter experts and educational experts.

Behavior was measured through a researcher-developed clinical scenario. A score of 0–10 was used to measure correct actions taken in a scenario. The clinical scenario scoring was tested with a small subgroup of 10 clinical nurses and content validity tested by four subject matter and educational experts. The scenario required approximately 10 minutes to complete and was scored in the LMS. Unlicensed staff on both units also received traditional education but were not included in the study.

Data Analysis

Descriptive statistics were used to analyze demographic information. Continuous variables were reported as means and standard deviations and categorical variables frequencies and percentages. Summary statistics and graphical representation were used to determine patterns and trends. Levine's test of homogeneity of variances and Shapiro–Wilk test for normality were used. A hypothesis test and confidence interval approach was used for continuous variables (Rosner, 2015). Knowledge and behavior outcomes were measured as change scores (i.e., posttest minus pretest). Simple comparisons using independent *t* tests tested knowledge and behavior change between intervention and control units, with Cohen's *d* for effect size. Additional regression analyses explored the relationships of selected demographic and professional characteristics to changes in knowledge and behavior within each group. To explore whether preintervention levels of knowledge and behavior impacted the potential for change, a less than adequate pretest score covariate (i.e., <80%) was added in the change in knowledge and behavior regression models to remove higher pretest scoring participants (i.e., ≥80%). Correlations between pairs of continuously scaled predictor variables explored significant relationships and collinearity in regression analysis. Variance inflation factor (VIF) was run in all regression analysis, values ~5 warranted concern for collinearity and were removed.

RESULTS

Sample Description

Eighty-four medical-surgical RNs participated in the study, with 44 in the VR intervention group and 40 in the traditional education control group. As shown in Table 2, the overall sample was predominately female (80.95%), with a mean age of 39.25. Most participants held a BSN degree (63.1%) and were not certified (65.48%). Half of the participants identified as Asian (50%), and 27.38% identified as White.

Primary Findings

Assumption tests showed no violations to normality, equal variances between samples, and a few outliers.

Aim 1: Changes in knowledge

Independent *t* tests with equal variances indicated no significant differences ($t = 1.4$, $p = .16$) for change in knowledge between group means ± standard deviation for the VR intervention (1.3 ± 1.39) and traditional education groups (1.75 ± 1.58). Cohen's *d* effect size was small at $d = 0.3$.

Aim 2: Changes in behavior

For change in behavior, no significant difference ($t = 0.67$, $p = .5$) was found between group means for the VR intervention (0.205 ± 0.84) and traditional education groups (0.325 ± 0.8).

TABLE 1 Groups, Interventions, and Times

	Intervention Group ($n = 44$)	Control Group ($n = 40$)
Time 1: Day 1	Demographics	Demographics
	Pretest (K)	Pretest (K)
	Pretest (B)	Pretest (B)
Time 2: Days 1–30	VR intervention	TE
	Posttest (K)	Posttest (K)
	Posttest (B)	Posttest (B)

Note. K = knowledge; B = behavior; Days 1–30 = measures collected anytime between Days 1 and 30; VR = virtual reality; TE = traditional education.

TABLE 2 Descriptive Statistics

Demographics	Mean ± Standard Deviation or *n* (%)		
	Overall Sample (*N* = 84)	VR Intervention (*n* = 44)	TE control (*n* = 40)
Age	39.25 ± 10.27	38.98 ± 10.06	39.55 ± 10.62
Years of experience	12.31 ± 9.10	12.03 ± 8.18	12.61 ± 10.12
Gender			
Female	68 (80.95)	35 (79.55)	33 (82.50)
Male	16 (19.05)	9 (20.45)	7 (17.50)
Race			
White	23 (27.38)	11 (25)	12 (30)
Asian	42 (50)	25 (56.82)	17 (42.5)
Black	3 (3.57)	1 (2.27)	2 (5)
Prefer not say/other	16 (19.05)	7 (15.91)	9 (22.5)
Highest nursing degree			
Bachelor's	53 (63.10)	25 (56.82)	28 (70)
Master's/doctorate/prof	23 (27.38)	14 (31.82)	9 (22.5)
Associate	8 (9.52)	5 (11.36)	3 (7.5)
Specialty certification			
No	55 (65.48)	26 (59.09)	29 (72.50)
Yes	29 (34.52)	18 (40.91)	11 (27.50)

Note. VR = virtual reality; TE = traditional education; prof = professional degree.

Cohen's d effect size was very small at $d = 0.15$. See Table 3 for outcome measures and t-test results.

Additional Findings

A significant relationship ($r = .89$, $p < .001$) was found between predictor variables (age and years of experience), and no significant relationships between continuous and outcome variables were noted. To address collinearity, age was removed after preliminary regression analysis yielded a VIF score of ~5. Four regression models were explored, two for change in knowledge (Model 1 [VR group], Model 2 [control]) and two for change in behavior (Model 3 [VR group], Model 4 [control]). VIF showed no concern for collinearity for Models 1–4 respectively at 1.18, 1.14, 1.13, and 1.1. To determine whether improvement was related to pre-intervention levels of knowledge and behavior, variables indicating less than adequate pretest knowledge and pretest behavior (i.e., scores of <80%) were included in the models. Table 3 shows results of the regression analysis. For changes in knowledge, Models 1 and 2 were statistically significant (intervention, $p < .001$; control, $p = .045$). Model 1 (VR group) indicated three significant predictors: low pretest knowledge ($p = .001$), gender ($p = .024$), and specialty certification ($p = .004$). For Model 2 (traditional education group/control), one significant predictor of pretest knowledge ($p = .004$) was found. For change in behavior, Model 4 was statistically significant (control, $p = .023$). Overall coefficient of multiple determination was assessed in terms of the R^2 values indicating percentage of variation explained by the linear model. Models 1–4 yielded a 43, 31, 24, and 34 percentage of variance explained, respectively.

DISCUSSION

This study found no significant differences in knowledge or behavior for VR and traditional education. The effect size for knowledge ($d = 0.3$) might be sufficient to generate interest with group differences potentially significant in large groups in comparison to the small sample used in this study. In addition, pretest scores impacted change in knowledge and behavior scores. A strong negative relationship between pretest scores and change in knowledge and behavior scores showed that the lower the pretest score, the higher the

TABLE 3 Scores on Outcome Measures, *t* Tests, and Regression Models

Measure	Mean (*SD*)	CI	*t* Score (*df*)	*p*	Effect Size[a]
Change in knowledge			1.4 (82)	.16	.3
Intervention	1.3 (1.39)	.873, 1.718			
Control	1.75 (1.58)	1.244, 2.256			
Change in behavior			.67 (82)	.5	.15
Intervention	.205 (0.84)	−.039, .448			
Control	.325 (0.8)	.055, .595			

Measure	Variables	Standardized Coefficient	VIF	95% CI	*p*	r^2
Change in knowledge						
Intervention	Model 1		1.18		**<.001***	.427
	Low pretest	.472	1.21	0.55, 2.11	**.001***	
	Years of experience	.109	1.1	−0.026, 0.063	.408	
	Gender	−.331	1.27	−2.093, 0.16	**.024***	
	Race	.133	1.14	−0.196, 0.583	.321	
	Highest degree	−.204	1.11	−0.936, 0.122	.128	
	Specialty cert.	.004	1.27	0.416, 2.007	**.004***	
Control	Model 2		1.14		**.045***	.309
	Low pretest	.488.	1.22	0.52, 2.59	**.004***	
	Years of experience	−.088	1.16	−0.063, 0.036	.577	
	Gender	−.044	1.07	−1.43, 1.072	.773	
	Race	.098	1.09	−0.297, 0.574	.521	
	Highest degree	−.075	1.10	−0.967, 0.590	.626	
	Specialty cert.	−.074	1.23	−1.401, 0.882	.646	
Change in behavior						
Intervention	Model 3		1.13		.097	.241
	Low pre-test	.363	1.03	0.216, 2.072	**.017***	
	Years experience	.106	1.04	−0.019, 0.04	.473	
	Gender	−.028	1.19	−0.677, 0.568	.860	
	Race	−.024	1.16	−0.281, 0.241	.876	
	Highest Degree	−.306	1.12	−0.705, 0.001	.051	
	Specialty Cert.	.137	1.23	−0.299, 0.74	.395	

(continues)

TABLE 3 Scores on Outcome Measures, *t* Tests, and Regression Models, Continued						
Measure	Variables	Standardized Coefficient	VIF	95% CI	*p*	r^2
Control	Model 4		1.10		**.023***	.344
	Low pretest	.533	1.09	0.59, 2.099	**.001***	
	Years of experience	−.041	1.15	−0.029, 0.022	.783	
	Gender	.113	1.07	−0.404, 0.899	.445	
	Race	.208	1.03	−0.063, 0.377	.156	
	Highest degree	.014	1.16	−0.398, 0.435	.929	
	Specialty cert.	.104	1.12	−0.374, 0.761	.493	

Note. SD = standard deviation; CI = confidence interval; *df* = degrees of freedom; VIF = variance inflation factor; CI = confidence interval.
[a]Effect size Cohen's *d*.
*Bolded *p* value indicates significant at <.05.

change in knowledge or behavior scores. These results were consistent with other studies (Lohre et al., 2020; Marei et al., 2017; Yu & Mann, 2021). Considering the cost and time limitations of a traditional education approach (Phillips et al., 2021), VRS might prove to be more economically efficient.

Limitations

The small sample size in this study limited generalizability. In addition, the educational intervention and grouping by units might have created inequities. A few participants expressed difficulty with VRS in terms of movement within the screen-based learning space and a mismatch in realness based on prior experience with VR headsets. Although platform orientation and practice was provided for learners, this orientation could be expanded in the future to ensure learner comfort with VR use. Computer hardware and software configuration of workstations at the inpatient sites also limited the VR and VRS software that could be used; further integration should involve information technology teams upon exploration of the product.

Implications for Education, NPD Practice, and Research

The effectiveness of the VRS and traditional education guides key stakeholders and policymakers in making decisions about the use of VR. NPD practitioners, academic nurse educators, and simulationists are strategically positioned to use VRS in practice and study its impact on learner and organizational outcomes. VR offers individualized active learning, but learners need additional support to adjust to changing practice and learning environments (Nair et al., 2023). Standardized language, aligned with the *Healthcare Simulation Dictionary* (Lioce et al., 2020) is strongly encouraged to advance and generate comparative outcomes in practice and research.

Because this study found no significant difference in VR and traditional learning outcomes, consideration of learners' preferences and cost-effectiveness of these modalities warrants examination. NPD practitioners are encouraged to explore applications and products through free demonstrations that most VR companies provide. These demos allow multiple users to evaluate content, relevance, and applicability to the setting and facilitate product comparisons. In addition, NPD practitioners can gain valuable experience and confidence practicing in the platforms. Discussions with product and technical teams facilitate development of business proposals to justify the return on investment and software integration.

CONCLUSIONS

VRS is an exciting new educational modality for NPD. The current experimental study found that VRS is a viable educational delivery modality compared to traditional approaches for healthcare education and NPD. Results validated existing traditional approaches and demonstrated encouraging potential for VRS.

References

Bakhos, D., Galvin, J., Aoustin, J. M., Robier, M., Kerneis, S., Bechet, G., Montembault, N., Laurent, S., Godey, B., & Aussedat, C. (2020). Training outcomes for audiology students using virtual reality or traditional training methods. *PLOS ONE*, *15*(12), e0243380. 10.1371/journal.pone.0243380

Berg, H., & Steinsbekk, A. (2020). Is individual practice in an immersive and interactive virtual reality application non-inferior to practicing with traditional equipment in learning systematic clinical observation? A randomized controlled trial. *BMC Medical Education*, *20*(1), 123. 10.1186/s12909-020-02030-7

Campbell, M. K., Piaggio, G., Elbourne, D. R., & Altman, D. G., CONSORT Group (2012). Consort 2010 statement: Extension to cluster randomised trials. *BMJ (Clinical Research Ed.)*, *345*, e5661. 10.1136/bmj.e5661

Centers for Disease Control and Prevention. (2019). *2019 Annual report for the emerging infections program for Clostridioides difficile infection*. https://www.cdc.gov/hai/eip/annual-cdi-report-2019.html. Retrieved February 5, 2023.

Finnimore, K., Smyth, W., Carrucan, J., & Nagle, C. (2023). Nurses' knowledge, practices and perceptions regarding *Clostridioides difficile*: Survey results. *Infection, Disease & Health*, *28*(1), 39–46. 10.1016/j.idh.2022.07.003

Harper, M. G., & Maloney, P. (Eds.) (2022). *Nursing professional development: Scope and standards of practice* (4th ed.). Association for Nursing Professional Development.

Izard, S. G., Juanes, J. A., García Peñalvo, F. J., Estella, J. M. G., Ledesma, M. J. S., & Ruisoto, P. (2018). Virtual reality as an educational and training tool for medicine. *Journal of Medical Systems*, *42*(3), 50. 10.1007/s10916-018-0900-2

Joda, T., Gallucci, G. O., Wismeijer, D., & Zitzmann, N. U. (2019). Augmented and virtual reality in dental medicine: A systematic review. *Computers in Biology and Medicine*, *108*, 93–100. 10.1016/j.compbiomed.2019.03.012

Kamkar, A. (2017). Education and engagement of front line staff to lower incidence of *Clostridium difficile*. *American Journal of Infection Control*, *45*(6), S99–S100. 10.1016/j.ajic.2017.04.156

Kang, K. A., Kim, S. J., Lee, M. N., Kim, M., & Kim, S. (2020). Comparison of learning effects of virtual reality simulation on nursing students caring for children with asthma. *International Journal of Environmental Research and Public Health*, *17*(22), 8417. 10.3390/ijerph17228417

Kolb, D. A. (2014). *Experiential learning: Experience as the source of learning and development*. FT Press.

Kyaw, B. M., Saxena, N., Posadzki, P., Vseteckova, J., Nikolaou, C. K., George, P. P., Divakar, U., Masiello, I., Kononowicz, A. A., Zary, N., & Tudor Car, L. (2019). Virtual reality for health professions education: Systematic review and meta-analysis by the digital health education collaboration. *Journal of Medical Internet Research*, *21*(1), e12959. 10.2196/12959

Lioce, L., Lopreiato, J., Downing, D., Chang, T. P., Robertson, J. M., Anderson, M., Diaz, D. A., Spain, A. E., & Terminology and Concepts Working Group. (2020). *Healthcare simulation dictionary* (2nd ed.). Agency for Healthcare Research and Quality. 10.23970/simulationv2

Lohre, R., Bois, A. J., Athwal, G. S., & Goel, D. P., Canadian Shoulder and Elbow Society (2020). Improved complex skill acquisition by immersive virtual reality training: A randomized controlled trial. *The Journal of Bone and Joint Surgery. American Volume*, *102*(6), e26. 10.2106/JBJS.19.00982

Marei, H. F., Donkers, J., Al-Eraky, M. M., & van Merrienboer, J. J. G. (2017). The effectiveness of sequencing virtual patients with lectures in a deductive or inductive learning approach. *Medical Teacher*, *39*(12), 1268–1274. 10.1080/0142159X.2017.1372563

Nair, J. M., Birkhoff, S., Mandel, D., & Thomas, A. (2023). The ever-changing work environment during COVID-19: Nurses' experiences in the early phase. *Journal for Nurses in Professional Development*, *39*(1), E1–E7. 10.1097/nnd.0000000000000782

Nielsen, C. S. R., Sanchez-Vargas, R., & Perez, A. (2019). *Clostridium difficile*: Reducing infections using an evidence-based practice initiative. *Clinical Journal of Oncology Nursing*, *23*(5), 482–486. 10.1188/19.CJON.482-486

ONeill, K., Robb, M., Kennedy, R., Bhattacharya, A., Dominici, N. R., & Murphy, A. (2018). Mobile technology, just-in-time learning and gamification: Innovative strategies for a CAUTI education program. *Online Journal of Nursing Informatics*, *22*(2), https://www.proquest.com/scholarly-journals/mobile-technology-just-time-learning-gamification/docview/2132298424/se-2

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), e11529. 10.2196/11529

Phillips, J. M., Feldman, K., Miller, P. S., & Galuska, L. (2021). The impact of boost methodology on nurse knowledge retention: A longitudinal, quasi-experimental sepsis simulation pilot study. *Journal for Nurses in Professional Development*, *37*(1), 3–11. 10.1097/nnd.0000000000000696

Poore, J. A., Cullen, D. L., & Schaar, G. L. (2014). Simulation-based interprofessional education guided by Kolb's experiential learning theory. *Clinical Simulation in Nursing*, *10*(5), e241–e247. 10.1016/j.ecns.2014.01.004

Pottle, J. (2019). Virtual reality and the transformation of medical education. *Future Healthcare Journal*, *6*(3), 181–185. 10.7861%2Ffhj.2019-0036

Ramirez, M. S. K. (2018). Influence of undergraduate nursing student teaching methods on learning standard precautions and transmission-based precautions: Experimental research. *Nurse Education Today*, *61*, 101–105. 10.1016/j.nedt.2017.11.007

Read, M. E., Olson, A. J., & Calderwood, M. S. (2020). Front-line education by infection preventionists helps reduce *Clostridioides difficile* infections. *American Journal of Infection Control*, *48*(2), 227–229. 10.1016/j.ajic.2019.08.002

Rosner, B. (2015). *Fundamentals of biostatistics*. Cengage Learning.

Scott, R. D., 2nd, Culler, S. D., & Rask, K. J. (2019). Understanding the economic impact of health care-associated infections: A cost perspective analysis. *Journal of Infusion Nursing*, *42*(2), 61–69. 10.1097/nan.0000000000000313

Shin, H., Rim, D., Kim, H., Park, S., & Shon, S. (2019). Educational characteristics of virtual simulation in nursing: An integrative review. *Clinical Simulation in Nursing*, *37*, 18–28. 10.1016/j.ecns.2019.08.002

Society for Simulation in Healthcare (2020). *Healthcare simulation dictionary* (2nd ed.). https://www.ssih.org/Dictionary

Tran, C., Toth-Pal, E., Ekblad, S., Fors, U., & Salminen, H. (2020). A virtual patient model for students' interprofessional learning in primary healthcare. *PLOS ONE*, *15*(9), e0238797. 10.1371/journal.pone.0238797

Xiong, J., Hsiang, E. L., He, Z., Zhan, T., & Wu, S. T. (2021). Augmented reality and virtual reality displays: Emerging technologies and future perspectives. *Light, Science & Applications*, *10*(1), 216. 10.1038/s41377-021-00658-8

Yu, M., & Mann, J. S. (2021). Development of virtual reality simulation program for high-risk neonatal infection control education. *Clinical Simulation in Nursing*, *50*, 19–26. 10.1016/j.ecns.2020.10.006

The test for this nursing continuing professional development activity can be taken online at www.NursingCenter.com/CE/JNPD.