Title
Impact of a Virtual Reality Simulation Modality Compared to Traditional Education on Nurse Knowledge, Nurse Behavior, and C'difficile Rates: A Randomized Controlled Trial and Return on Investment Analysis

Author
Phillips, Jessica M.

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Impact of a Virtual Reality Simulation Modality Compared to Traditional Education on Nurse Knowledge, Nurse Behavior, and C'difficile Rates: A Randomized Controlled Trial and Return on Investment Analysis

A dissertation submitted in partial satisfaction of the
requirements for the degree Doctor of Philosophy
in Nursing

by

Jessica Marie Phillips

2023

ABSTRACT OF THE DISSERTATION

Impact of a Virtual Reality Simulation Modality Compared to Traditional Education on Nurse Knowledge, Nurse Behavior, and C'difficile Rates: A Randomized Controlled Trial and Return on Investment Analysis

by

Jessica Marie Phillips

Doctor of Philosophy in Nursing

University of California, Los Angeles, 2023

Professor Holli DeVon, Chair

Abstract

Background. Effective educational delivery requires that nursing professional development (NPD) practitioners engage registered nurses (RNs) to address rising healthcare-associated infections (HAIs). Four percent of patients in the U.S. and 10% worldwide are diagnosed with an infection while in the hospital. HAIs have increased during the COVID pandemic despite current infection prevention control practices and educational approaches. C'*difficile* costs range from $11,000-17,260 per case. Health system patient data at the study site illustrated C*'difficile* infection rates higher than the benchmark, with 26 units underperforming when compared to the standardized infection ratio (SIR) or <1 goal. Gaps in the literature illustrated inconsistent links in education to practice.

Aims. The following research questions were explored: In a large academic health system setting, does virtual reality simulation (VRS) compared to traditional education (TE) improve

RN knowledge and behavior; as well as, C'difficile rates? Is there a return on investment (ROI) for these approaches? Aims 1-2 tested the effect of the delivery format on knowledge and behavior. Aim 3 compared C'difficile rates after delivering the two educational modalities. Aim 4 explored ROI of the two educational methods.

Methods. An experimental randomized controlled trial (RCT) design with two groups was used to answer the research questions. One pair of matched inpatient units was randomly selected for participation, assigned to either the VRS or TE group. Instruments used included the Cognitive, Affective, and Psychomotor Perceived (CAP) Learning Scale and a researcher-developed knowledge assessment and clinical behavior scoring tool. Data were analyzed using t-tests, multiple regression, the Poisson distribution, and financial equations.

Results. Eighty-four medical-surgical RNs participated in the study (n=44 VRS, n=40 TE). No statistically significant differences between groups were found. There was no significant differences (t=1.4, p =.16) for change in mean knowledge between groups (Cohen's d=.3) or change in mean behavior (t=.67, p =.5) between groups (Cohen's d =.15). Statistical significance was found in regression analysis when considering pre-intervention scores. The TE group had no statistically significant C'*difficile* rate differences between 1-month pre-intervention to 1-month post-intervention. The VRS group had significantly lower rates for these intervals (p =.0003). C'*difficile* rates were significantly lower for both groups for the 3-month post intervention period as compared to the 10-month period pre-intervention. Financial analysis showed a ROI for both modalities, with VRS having higher yields over time.

Conclusions. Both VRS and TE modalities reduced C'*difficile* rates and produced positive economic returns on investment to inform future resource allocation.

The dissertation of Jessica Marie Phillips is approved.

Mary-Lynn Brecht

Carol Pavlish

Janet Mentes

Mary Harper

Holli DeVon, Committee Chair

University of California, Los Angeles

2023

Dedication

To all my parents, for always being my biggest supporters and cheerleaders, and my colleagues for lending their time and expertise.

To my significant other, thank you for always believing in me, loving me, and ensuring I was balanced and kept things in perspective.

And finally, to nursing professional development practitioners and nursing educators everywhere; especially the next generation, remember you matter and make a difference to your organizations and departments each and every day.

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List of Acronyms

ANCC: American Nurses Credentialing Center's

AR: Augmented Reality

CAP: Cognitive, Affective, and Psychomotor

CDC: Center for Disease Control and Prevention

CDI: Clostridioides difficile or C. *difficile*

CI: Confidence Interval

CINAHL: Cumulative Index to Nursing and Allied Health Literature

CMS: Centers for Medicare and Medicaid Services

CCAT: Crowe Critical Appraisal Tool Form

HAI: Hospital-associated Infection

INACSL: International Association for Clinical Simulation and Learning

LMS: Learning Management System

NPD: Nursing Professional Development

PTAP: Practice Transition Accreditation Program

RCT: Randomized Controlled Trial

RN: Registered Nurse

ROI: Return on Investment

SIR: Standardized Infection Ratio

TE: Traditional Education

VR: Virtual Reality

VRS: Virtual Reality Simulation

WHO: World Health Organization

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Vita/Biographical Sketch

Masters of Science, School of Nursing (MSN), 2008
University of California, University of California Los Angeles
Practicum: Oncology and Hematology
Fellowship: Graduate Nursing Fellowship 2006-2008

Masters of Science (MS), Bachelor of Science (BS), 1995-2001
Southern Illinois University, Carbondale
Specialty: Education, Health Education (Teacher Education Training)
Awards: Teach for America, Health Education Excellence Award
Scholarships: Elizabeth Eames Women's Studies Graduate
Honors: Phi Kappa Phi Honor Society, Dean's List, Honors Student

Experience

Manager, Nursing Professional Development (2017-current)
University of California, Los Angeles, UCLA Health

Nursing Professional Development Specialist (2014-2017)
University of California, Los Angeles, UCLA Health

Clinical Nurse I-IV (2008-2014)
Cedars Sinai Medical Center, Los Angeles, California

Licenses

Registered Nurse, State of California, 737320

Publications

Galuska, L., Phillips, J, M., Anderson, K., & Miller, P. S. (May, 2023). *A health system approach to evaluating nurse wellbeing and designing interventions* [manuscript submitted for publication]. Center for Nursing Excellence, UCLA Health.

ANPD (Feb, 2023). *Health literacy and its role in patient advocacy and health equity*. *NPD in motion.* Featured interview with Jessica M. Phillips & Julie Gaspar. Retrieved Feb 15, 2023 at https://www.anpd.org/NPD-In-Motion/Article/health-literacy-and-its-role-in-patient-advocacy-and-health-equity.

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Podium and Poster Presentations

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Phillips, J. M. (May, 2023). Addressing onboarding and orientation of new graduates with minimal clinical experience. Webinar Panel: Organization of Healthcare Educators, Los Angeles area ANPD affiliate.

Phillips, J. M., Li, C., Gaspar, J. (May, 2023). Impact of a virtual reality simulation modality compared to traditional education on nurse knowledge, nurse behavior, and C'difficile rates: A randomized controlled trial and return on investment analysis. Session: Podium, UCLA Health Nursing Science and Innovation Conference in Los Angeles, CA.

Phillips, J. M. (April, 2023). RCT of virtual reality effect on nursing knowledge, behavior, and C'Difficile rates. Session: Poster, Western Institute of Nursing in Tucson, AZ.

Phillips, J. M., & Anderson, K. (March, 2023). A systematic approach to evaluating nurse wellbeing and designing solutions. Keynote Presentation Huntington Hospital 5th Annual Research Conference in Pasadena, CA.

Gaspar, J. & Phillips, J. M. (March, 2023). Assessment of readability and health literacy: An issue of equity. Session: Podium, ANPD Annual Convention. Atlanta, GA.

Galuska, L., Phillips, J. M., Anderson, K. & clinical nurses (Jan, 2023). Nursing well-being research study. Presentation: UCLA Health Nursing Grand Rounds.

Galuska, L., Phillips, J. M., & Anderson, K. (Jan., Feb, 2023). A health system approach to evaluating nurse wellbeing and designing interventions. Sigma Event: Creating Healthy Workplace Environments. Podium Presenter & Austin, TX; ACNL 45th Annual Conference. Rancho Mirage, CA. Poster Presenter.

Chapter One: Introduction

Emergence of Virtual Reality Simulation

Effective educational delivery requires nursing professional development (NPD) practitioners engage registered nurses (RNs) to address rising healthcare-associated infections (HAIs). Virtual reality (VR) has emerged as a widely adopted and growing simulation method, defined as a computer-generated environment based on learner presence and sensory stimulation (i.e., immersion) in the learning space (Farshid et al., 2018; Kardong-Edgren et al., 2019; Ross et al., 2022). Validation of transferable skills to practice settings is the main goal of education for healthcare workforce training (Carruth, 2017).

Virtual Reality and Traditional Modalities

Virtual reality is a computer-generated learning environment that can range from 3-dimensional 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 [SSH], 2020). Virtual reality platforms resemble practice environments to facilitate application of learning (SSH, 2020). Interactive 360 video systems and VR simulators offer visualization of tasks, videos, and simulations where learners can perform tasks virtually based on course objectives (Izard et al., 2018). Virtual reality simulation uses keyboards, mouse, speech and/or voice recognition devices, motion sensors, and avatars (SSH, 2020). Virtual reality and screen-based simulation platforms provide direct performance feedback, tracking, objective evaluation, and reporting capabilities essential to healthcare training (Huang et al., 2018).

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

C. *difficile* Priority

A focus of education in healthcare has been Clostridioides difficile or C. *difficile* (CDI), a bacterium germ that can cause diarrhea. Symptoms range from diarrhea to life-threatening damages to the colon and other organs, and can lead to death. The incidence rate of CDI in the United States are 121.2 cases per 100,000 persons (CDC, 2019). Nearly, 1 out of every 6 patients are re-infected within 2-8 weeks and 1 out of 11 people over the age 65 diagnosed die within a month (CDC, 2023). CDI costs per case are between $11,000-17,260 (Scott et al, 2019). Preventative measures in healthcare settings have included avoiding unnecessary use of antibiotics, hand hygiene, contact precautions, and high-touch environmental cleaning (Nielsen et al., 2019). Educational interventions that address knowledge and behavior gaps of healthcare workers has been shown to reduce CDI incidence (Finnimore et al., 2023; Kamkar, 2017: Read, 2020).

Registered nurses in inpatient acute settings have substantial patient contact and perform vital roles in CDI prevention by ensuring that standard infection prevention and transmission safeguards are followed. Standard precautions for all patients include personal protective equipment, hand hygiene, and safe handling and disposal (CDC, 2021). Transmission safeguards represent additional isolation precautions taken when patients are infected. Effectiveness of these safeguards are captured through nursing-sensitive indicators and measure the impact of nursing and unlicensed staff activities related to incidence.

Cost Considerations

Virtual reality and screen-based simulation can offer low-cost educational solutions with the use of head mounts and mobile systems to facilitate knowledge transfer, presence, realism, performance measurement (i.e., accuracy, time-on-task, order), and user-experience feedback (Carruth, 2017). These methods are cost-effective and offer repetition and training on-demand (SSH, 2020). Virtual reality software and hardware costs for headsets and computer set-up or scenarios range from $3,000-$15,000. Additional operational costs are determined by number of users (Pottle, 2019). During the COVID-19 pandemic, VR provided a cost-effective approach to train healthcare learners through generation of real-life environments, higher order thinking, learner interest, and safe learning spaces (Singh et al., 2020). C'*difficile* known costs can be used to measure the impact of NPD initiatives to drive decision-making and resource allocation (Opperman et al., 2022a; Opperman et al., 2022b)

Statement of Study Purpose

Patient outcome data at a large academic health system illustrated that multiple units were underperforming when compared to the standardized infection ratio (SIR) for CDI. Traditional educational approaches were not filling the professional practice gaps identified by nursing, making this a critical area of research. This dissertation adds to the state of the science by contributing a review of the literature and exploring the impact of VRS compared to TE on nurse knowledge and behavior; as well as, CDI rates in a health system.

Specific Aims

1. To conduct an integrative review to explore the current state of learning outcomes derived from virtual simulation modalities and determine if it is a viable option to deliver healthcare education and nursing professional development.
2. To test the effect of the delivery format of VRS compared to TE on nurse knowledge.

3. To test the effect of the delivery format of VRS compared to TE on nurse behavior.
4. To compare CDI rates for VRS and TE after delivering the two educational modalities.
5. To explore the return on investment (ROI) of these two educational delivery methods.

Content of the Dissertation: Three Manuscripts

The content of the dissertation features three manuscripts, which are as follows:

1. Chapter Two: Virtual Reality and Screen-Based Simulation Learner Outcomes Using Kirkpatrick's Evaluation Levels: An Integrative Review (Aim 1). This chapter features an integrative review of the literature from 2008-2021 describing the state of VR and screen-based simulation usage, settings, subjects, and learner outcomes in healthcare settings. Main results showed that when measured, learner reaction (satisfaction, attitude, perception, and confidence) increased or improved 76%, learning 73%, and behavior 89% of the time for VR compared to other methods.
2. Chapter Three: Effect of a Virtual Reality Simulation Modality on Registered Nurse Knowledge and Behavior Related to C'*difficile* Prevention: An Experimental, Randomized Controlled Trial Study (Aims 2 and 3). This chapter describes an experimental, randomized controlled trial with a sample of clinical RNs to compare effectiveness of VRS and TE on knowledge and behavior related to C'difficile prevention. Eighty-four medical-surgical RNs participated in the study, with 44 in the VRS intervention group and 40 in the control group. No significant differences were

found in the effectiveness of the two modalities, suggesting the usefulness of VRS as a teaching methodology.

3. Chapter Four: Impact of a Virtual Reality Simulation Modality Compared to Traditional Education on C'Difficile Rates: A Randomized Controlled Trial and Return on Investment Analysis (Aims 4 and 5). This chapter also describes an experimental randomized controlled trial design with a sample of RNs on two inpatient units in a large academic health system to evaluate the impact of VRS compared to TE on C'difficile rates. Return on investment of nursing professional development activities was also measured to support decision-making and resource allocation. C'difficile rates were significantly lower for both groups for the 3-month post intervention period as compared to the 10-month period pre-intervention. Financial analysis showed a return on investment for both modalities, with VRS having higher yields over time.
4. Chapter Five: Dissertation Summary. The dissertation summary will provide a summary of study significance as well as recommendations for future research.

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Chapter Two: Literature Review (First Manuscript)

Virtual Reality and Screen-Based Simulation Learner Outcomes Using Kirkpatrick's Evaluation Levels: An Integrative Review

Abstract

Background. Simulation-based learning, including virtual reality (VR) and screen-based simulation, has emerged as widely adopted virtual methods that can provide an effective way to enhance learning. The purpose of this integrative review was to explore the current state of learning outcomes derived from virtual simulation modalities and determine if it is a viable option to deliver healthcare education and nursing professional development.

Methods. Whittemore and Knafl's (2005) integrative review framework was followed for this review. PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Web of Science, and ESBSCO databases were searched and yielded 499 articles. Data were analyzed in three phases and learning outcomes synthesized according to the four evaluation levels in Kirkpatrick's Model (1996).

Results. Twenty-five articles met inclusion criteria. Of the studies reviewed, 88% showed improved outcomes including high levels of learner satisfaction (76%), knowledge or skill acquisition (73%), and behavior change (89%). Organizational outcomes were not reported.

Conclusions. VR and screen-based simulation are effective educational delivery options for healthcare related education and nursing professional development, although more robust research that measures higher level learner outcomes is needed.

Background

Simulation-based learning has expanded in the past decade to improve healthcare performance and health system processes. Given that published research has not aligned with definitions of healthcare simulation approaches (Lioce et al., 2020) and there is a lack of available research along any one defined approach (Farra et al., 2019; Yu & Mann, 2021), an inclusive search was conducted of both screen-based simulation and virtual reality approaches to evaluate their use in healthcare education and nursing professional development.

Virtual reality (VR) has emerged as a widely adopted and growing simulation method, defined as a computer-generated environment based on the degree of learner presence and sensory stimulation (i.e., immersion) in the learning space (Farshid et al., 2018; Kardong-Edgren et al., 2019; Ross et al., 2022). Immersive VR uses 3-D head-mounted displays and other user-interfaces such as a keyboard, mouse, voice recognition, motion, avatars, and haptic devices (Kardong-Edgren et al., 2019; Lioce et al., 2020; Padilha et al., 2019; Society for Simulation in Healthcare, 2020). Virtual simulation reality and virtual simulation definitions are terms used to describe VR (Society for Simulation in Healthcare, 2020). Less immersive learning offers repetition and accessibility of content through screen-based simulation (Kyaw et al., 2019; Lioce et al., 2020; Lohre et al., 2020). Mixed reality approaches are defined here given their frequent comparison to VR and are described as a hybrid combination of real-world and simulation that mimic clinical situations and settings so learners can respond to healthcare-related scenarios and develop clinical skills and critical thinking without harming patients (Lioce et al., 2020; Marei et al., 2017; Padilha et al., 2019). VR environments create immediacy and relevance to link acquisition and application of learning to healthcare practice settings (Society for Simulation in Healthcare, 2020). VR and screen-based simulation offers a multitude of immersive experiences for regulatory safety training, education, competency, and professional development (Kyaw et al., 2019; Pottle, 2019; Rasmussen et al., 2014).

Validation of transferable skills to practice settings is the main goal of education for healthcare workforce training (Carruth, 2017). VR and screen-based simulation can offer low-cost educational solutions with the use of head mounts and mobile systems to facilitate knowledge transfer, presence, realism, performance measurement (i.e., accuracy, time-on-task, order), and user-experience feedback (Carruth, 2017). During the COVID-19 pandemic, VR applications provided a responsive and cost-effective approach to train healthcare learners through generation of real-life environments, higher order thinking, learner interest, and safe learning spaces (Singh et al., 2020). VR and screen-based simulation platforms provide direct performance feedback, tracking, objective evaluation, and reporting capabilities essential to all training (Huang et al., 2018).

Studies have explored healthcare topics related to provision of care through use of VR and screen-based simulation in nursing, medical, and dentistry fields with favorable outcomes (Lohre et al., 2020; Marei et al., 2017; ONeill et al., 2018; Phillips et al., 2021; Ramirez, 2018; Rutherford-Hemming et al., 2016; Voutilainen et al. 2017; Yu & Mann, 2021). Conversely, traditional or in-person educational environments have posed cost and time limitations (Andreatta et al., 2010; Baldwin et al., 2010; Reime et al., 2008). The overall purpose of this integrative review was to describe the current state of VR and screen-based simulation use in healthcare settings to set the stage for future nursing research on its efficacy. The review included VR, screen-based simulation, mixed reality environment modalities, and an expansive timeframe since VR is relatively new and research is meager.

Methods

Review Process

Cooper's Framework provided a conceptual guide to drive the steps undertaken for this review (Cooper et al., 2019; Cooper, 2015; Cooper & Koenka, 2012). Seven steps included: formulating the problem, searching the literature, gathering information from synthesis, evaluating the quality of evidence, analyzing and integrating the outcomes of syntheses, interpreting the evidence, and presenting results. To allow for experimental and non-experimental methodologies, the Whittemore and Knafl (2005) Framework was used as a specific guide for this review as outlined in the subsequent sections. Strategies used here were: (1) clear identification of the problem, (2) defined literature search strategies, (3) qualitative evaluation of the data, (4) data analysis to determine meaning through grouping and categorizing, and (5) presentation of results to capture the depth and breadth of the topic through tables and description (Hopia et al., 2016; Whittemore & Knafl, 2005).

Problem Identification

Based on the emergence of VR and screen-based simulation in healthcare settings, implementation of its effectiveness has not been adequately evaluated. To set the stage for future nursing research on efficacy in healthcare settings, the following two questions guided the review: (1) What is the current state of learning outcomes derived from VR and screen-based simulation? and (2) Is VR and screen-based simulation a viable approach to deliver healthcare related education and nursing professional development?

Defined Literature Search Strategies

Primary literature was collected through a systematic search strategy of databases using keywords related to the problem and purpose of the review (Whittemore & Knafl, 2005). Electronic databases searched included: PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Web of Science, and ESBSCO. Key words with Boolean operator strategies used were: “virtual reality,” OR “virtual simulation,” OR “screen-based simulation,” with combined search variations of AND “digital learning,” “online learning,” “nursing” “nursing education,” “skill development,” “simulation,” “virtual reality simulation,” “VR,” “healthcare education,” “learning modalities,” “simulated virtual modalities,” and “clinical outcomes.” This initial search yielded 1209 articles. To further limit the number of articles, additional filters were added, including a date range of 2008 to 2021, peer-reviewed academic journals, English language, and adult subjects. These limitations reduced the total to 499 articles. After excluding articles with incomplete outcome data, instrument description, or applicable focus to healthcare settings, 96 articles remained and were reviewed for quality.

Qualitative Evaluation of Data

Each article was evaluated for quality and relevance by the first author (Whittemore & Knafl, 2005). The Crowe Critical Appraisal Tool Form (CCAT) was used to evaluate quality and minimize bias related to methodologies used in the research articles selected (Crowe, 2013). Articles with a rating of less than 35 out of 40 were excluded, reducing the article count to 25. Inclusion and exclusion criteria in Table 1 and the PRISMA flow diagram in Figure 1 were used to assess for relevance related to the purpose of the review (Page et al., 2021).

Data Analysis and Presentation

Data were analyzed in three phases. Data derived from this review were then presented in tables and in the results section to show the synthesis of results related to the two guiding questions. In Phase I, content analysis was conducted by color coding the evidence for themes and use of a theoretical model. Evidence sections included the purpose, subjects and settings, methods, analysis, results, and discussion. During Phase II, articles were numbered alphabetically and outcomes synthesized through the framework of Kirkpatrick’s (1996) four evaluation levels, as shown in Tables 2 and 3. The Kirkpatrick Framework describes levels as (1) learner reaction or response, (2) knowledge or skills acquisition, (3) behavior change or performance measure, and (4) organizational return on investment or patient outcomes (Kirkpatrick, 1996). Lastly, in Phase III the entire body of literature was evaluated based on modality, level of evidence, and outcomes as shown in Table 4. Studies were categorized based on the Helene Fuld Health Trust National Institute for Evidence-based Practice in Nursing and Healthcare levels I through VII (Melnyk et al., 2018), as described in Table 5.

Results

Fifty-six percent of studies were controlled trials with (n=7) and without randomization (n=7), followed by 20% case control or cohort (n=5), and 20% qualitative or descriptive studies (n=5). One systematic virtual education review (4%) was included given its contribution to the aims. No qualitative systematic reviews or expert opinion studies were found.

Question 1 – What is the current state?

VR and Screen-based Simulation

Several of the studies used more than one virtual modality in intervention, control, or comparison groups exploring virtual modalities (Alvarez & Dal Sasso, 2011; Berg & Steinsbekk, 2020: Marei et al., 2017; Rutherford-Hemming et al., 2016; Tran et al., 2020: Tachannen et al., 2018; Wong et al., 2016). Traditional learning, defined as asynchronous or synchronous learning lecture, classroom or lab setting served as a comparison in multiple studies (n=8) to VR modalities (Aebersold et al., 2012; Bakhos et al., 2020; Berg & Steinsbekk, 2020; Botezatu et al., 2010; Feng et al., 2013; Marei et al., 2017; Pilieci et al., 2018; Soltaniemehr et al., 2019). Virtual reality simulation (VRS) accounted for most studies (56%, n=14) (Aebersold et al., 2012; Alvarez & Dal Sasso, 2011; Botezatu et al., 2010; Farra et al., 2019; Kang et al., 2020; Liaw et al., 2015; Marei et al., 2017; Padilha et al., 2019; Rutherford-Hemming et al., 2016; Tenorio da Silva et al., 2020; Tran et al., 2020; Tachannen et al., 2018; Watari et al., 2020; Wong et al., 2016). Blending learning approaches, defined as combined virtual modalities (i.e., mixed reality, virtual communities, web-based learning, and learning objects in learning management systems) were explored in 12 studies (Alvarez & Dal Sasso, 2011; Feng et al., 2013; Fogg et al., 2013; Georg & Zary, 2014; Kohan et al., 2017; Marei et al., 2017; Pilieci et al., 2018; Rutherford-Hemming et al., 2016; Soltanimehr et al., 2019; Tran et al., 2020; Tachannen et al., 2018; Wong et al., 2016). Five studies explored highly immersive VR with advanced technology features (Bakhos et al., 2020; Bartlett et al., 2020; Berg et al., 2020; Dubrovsky et al., 2017; Markransky & Lilleholt, 2018).

Subjects and Settings

The majority of studies (68%) focused on student subjects in various healthcare related fields of study. These fields included general university (n=1) (Markransky & Lilleholt, 2018), audiology (n=1) (Aebersold et al., 2012), pharmacy (n=1) (Tenorio da Silva et al., 2020), dental (n=2) (Marei et al., 2017; Soltanimehr et al., 2019), medicine (n=5) (Bartlett et al., 2020; Botezatu et al., 2010, Kohan et al., 2017; Pilieci et al., 2018; Watari et al., 2020) and nursing (n=8) (Aebersold et al., 2012; Alvarez & Dal Sasso, 2011; Berg & Steinsbekk, 2020; Dubrovsky et al., 2017; Fogg et al., 2013; Georg & Zary, 2014; Kang et al., 2020; Padilha et al., 2019).

Four studies included interprofessional learners (Farra et al., 2019; Tran et al., 2020; Tachannen et al., 2018; Wong et al., 2016). Farra et al. (2019) included nurses, monitor technicians, advanced practice nurses, medical doctors, and respiratory therapists in VRS. Tran et al. (2020) included student subjects from nursing, medical, physiotherapy, and occupational therapy and Tachannen et al. (2018) nursing, medicine, pharmacy, and social work university programs. Wong and colleague's (2016) subjects were pre-licensure healthcare students in medicine, midwifery, pharmacy, nursing, dentistry, counseling, psychology, and computer science.

Theoretical Model

Twenty percent of studies (n=5) reported using a model or theoretical framework. Of these, four used educational models and one used nursing theory. Experiential learning theory was used in two articles: one explored the effects of Kolb's Learning Styles (Fogg et al., 2013; Kolb, 2014) and the other a virtual patient IPE model was developed from social constructivist and experiential learning theories (Tran et al., 2020). Farra et al. (2019) used Bloom's Taxonomy in developing educational learning objectives and Kirkpatrick's Evaluation Levels. Control-Value Theory of Achievement was used to explore student emotion and its impact on outcomes (Makransky & Lilleholt, 2018). The Outcome Present State Model, the only nursing model, explored clinical reasoning development (Georg & Zary, 2014).

Educational Delivery Strategies

Three research teams created and adapted software, programs, or validated tools. For example, Georg & Zary (2014) created a Virtual Interactive Care System using a Virtual Patient Nursing Design and Nursing Activity Model to engage learners in clinical reasoning. VirSam application was also developed and evaluated as an immersive VR modality for practice of the airway, breathing, circulation, disability, exposure (ABCDE) approach (Berg & Steinsbekk, 2020). Tenorio da Silva et al. (2020) created and evaluated software called Virtual Patient for Geriatric Education by enlisting pharmacy and computer science departments.

Six studies used virtual blended learning delivery approaches. Two blended learning examples included an online open access multi-user virtual environment called Second Life, where students can interact in a virtual environment (Aebersold et al., 2012) and the other was a tablet problem-based learning environment with small educational units called virtual learning objects (Alvarez & Dal Sasso, 2011). Soltanimehr et al. (2019) used a learning management system for radiographic interpretations. Collaborative virtual patient IPE platforms used blended approaches based on the setting. Additionally, Tschannen and colleagues (2018) taught Crew Resource Management through a combination of self-learning modules and simulations using Second Life (Tschannen et al., 2018). Finally, Tran et al. (2020) explored a virtual patient IPE model and Wong et al. (2016) evaluated a Virtual Interprofessional Patients-Computer-Assisted Reproductive Health Education for Students.

Notable differences in immersive VR delivery strategies based on cognitive load (i.e., difficulty of topic) and advanced technology were noted in five studies. First, Bartlett et al. (2020) used an immersive Simbionix AnthroMentor VR simulator with computer monitors, mannequins, and haptic devices with tactile feedback. Second, a VR platform to proxy an ED triage was simulated with computer screens and avatars (Dubovsky et al., 2017). Third, VRS and clinical updates modules were employed with a keyboard, head mounted displays, and game pads to simulate an emergency evaluation training for neonatal intensive care staff (Farra et al., 2019). Fourth, immersive and desktop VR were compared using a cell phone, VR head mounted displays, and computer screens with multiple sensory environments (Makransky & Lilleholt, 2018). Lastly, Bakhos et al. (2020) used immersive VRS for audiometric training to simulate seven clinical cases from beginner to expert levels.

Eleven studies used mainstream VRS or virtual learning delivery strategies to simulate practice. Four of these studies used high fidelity with a simulator, low fidelity using realistic environments, or virtual patient simulations (Kang et al., 2020; Padilha et al., 2019; Rutherford-

Hemming et al., 2019; Watari et al., 2020). Other virtual delivery methods included a web-based virtual patient simulator or elearning for medical education (Botezatu et al., 2010; Kohan et al., 2017; Marei et al., 2017), elearning computer assisted with simulations and case scenarios (Feng et al., 2013), multimedia web-based simulation for developing nurse competencies (Liaw et al., 2015), virtual patient health stories based on learning styles (Fogg et al., 2013), and an experiential learner-paced video (Pilieci et al., 2018).

Question 2 – Is VR and Screen-based Simulation a viable approach?

Educational outcomes were synthesized using Kirkpatrick's four program evaluation levels: (1) reaction or response to the learning, (2) learning that takes place (e.g., increase in knowledge, skills, or experience), (3) behavior change or intent to change, and (4) results at the organization level (e.g., patient outcomes, return on investment) (Kirkpatrick, 1996). No level four outcomes were reported in the studies reviewed.

Level 1 Reaction

Satisfaction, attitude, perception, and confidence outcomes were main themes used to describe learner reaction (n=17). When measured, thirteen studies (76%) reported a positive learner reaction to VR modalities. Additionally, negative reactions (n=1), no change in reaction (n=1), and mixed reactions (n=2) were noted. Four studies reported satisfaction with the virtual learning experience. For example, satisfaction score means of 3.55 for "reinforced objectives" and 3.18 for "realness" on a 5-point scale were reported by Aebersold et al. (2012). Similarly, Bakhos et al. (2020) reported VR satisfaction ratings of 100% compared to 74% for traditional education methods (Bakhos et al., 2020). Berg & Steinsbekk (2020) achieved greater student satisfaction in VR in practice from pre to post activity. Finally, Padilha et al. (2019) reported statistically significant higher levels of participant satisfaction with high (i.e., virtual clinical simulator) verse low fidelity simulation (i.e., realistic environment) d=1.33 ($p<.001$).

Attitude was measured in three studies. Dubovsky et al., (2017) found, positive attitudes toward VR with strong correlations of participants feeling successful and satisfied with the ED workload compared to the simulated VR experience (>.75). Mean between group scores on a Geriatrics Attitudes Scale after using the VR software were statistically significant ($p<.01$) with more positive attitudes from pre to post-educational intervention (Tenorio da Silva et al., 2020). Lastly, positive attitudes toward IPE were noted both before and after the virtual patient modality was used for education (Wong et al., 2016).

Four studies reported perceived confidence pre to post-VR modalities. For example, perceived participant confidence of meeting learning objectives (measured by a Likert scale) was 72% for traditional education compared to 92% for VR (Bakhos et al., 2020). Dubovsky et al. (2017) reported greater confidence with the VR experience correlated to PPE non-adherence (-.81). Kang et al. (2020) found statistically significant higher confidence measures with vSim groups compared to the high-fidelity sim groups alone. Farra et al. (2019) did not find significant differences in confidence measures when comparing VRS and web-based clinical updates.

Perceived usability of VR technology was reported in eight studies. Qualitative themes of flexibility of access, learner choices and preferences, relevance, and use of critical thinking emerged (Alvarez & Dal Sasso, 2011; Liaw et al., 2015). Based on a System Usability Scale, absolute differences out of 100 were noted with two statistically significant categories illustrating that VR was a "good way to learn" at 46% of points (95% CI 36.5 to 56.6) and "appropriate for the subject" at 36.9% of points (95% CI 26.8 to 47) (Berg & Steinsbekk, 2020). Georg & Zary (2014) measured perceived usefulness of a virtual patient through authentic patient encounters, professional approach, coaching during consultation, learning effect on consultation, and overall judgment. Eighty percent of their subjects reported being actively engaged in the educational intervention and 74% rated the experience as worthwhile. Similarly, Tran et al. (2020) found that virtual patients facilitated the learning process, was beneficial for learners, enhanced roles and competencies, and led to interprofessional planning to improve patient outcomes. Usability effects were significant with small effect sizes and psychological factors with large effect sizes related to presence (1.67), motivation (1.28), immediacy of control (.99), and enjoyment (.94) (Makransky & Lilleholt, 2018). Learning (4.9) and intent to use skills and knowledge (4.9) after VRS on a 5-point scale was rated higher than controls (Tschannen et al., 2018). Conversely, Kohan et al. (2017) identified cognitive barriers in virtual environments such as, information overload, attentiveness, communication barriers, ambiguity in the environment, and poor coping.

Level 2 Learning

Knowledge acquisition was used as evidence of level two learning in (n=15) studies. When measured, eleven studies (73%) reported learning gains using VR modalities. Additionally, no change in learning (n=3) and a mixed reaction (n=1) was reported. Knowledge was measured through pre and post-test assessment or exams. Instruments included researcher developed tests, course exams, and standardized tools. Twelve studies reported significant improvement in pre to post-test scores. Use of a mixed virtual environment modality demonstrated a statistically significant increase in knowledge in four studies (Alvarez & Dal Sasso, 2011; Tenoro da Silva, 2020; Tschannen et al., 2018; Watari et al., 2020). Botezatu et al. (2010) found significantly higher scores for VSR intervention compared to control post exam ($p<.001$). A three group comparison with lecture and (i.e., vSim, high fidelity sim, and vSim plus high fidelity) found statistical significance for each group pre to post-test on knowledge with post hoc analysis mean difference higher for the two vSim groups compared to high fidelity sim (Kang et al., 2020). Finally, after control and intervention group randomization, and controlling for pre-test scores, Liaw et al. (2015) found post-test scores for VRS/web-based simulation interventions significantly higher ($p<.001$).

A few studies considered outcome measures such as knowledge acquisition and or knowledge transfer. For example, Marei et al. (2017) explored the impact of virtual patients through inductive and deductive learning approaches and found gender to be an effect modifier on knowledge measures. Two surgical topics (i.e., one condition vs. multiple conditions) were explored with the second having higher cognitive load (i.e., distractions or complicated instructions/concepts). Results showed statistical significance for learning approaches and gender ($p<.05$) on knowledge transfer topic one, knowledge acquisition topic two, and knowledge transfer topic two; no statistical significance was found between learning approaches (i.e., inductive, deductive), with males more impacted by learning approach (Marei et al., 2017). Padilha et al. (2017) also found that subjects exposed to the high-fidelity VSR had knowledge assessment gains 1.19-fold higher than controls ($p<.001$). Finally, Pilieci et al. (2018) demonstrated increases in post-test scores for virtual modalities ($p<.001$).

Rutherford-Hemming et al. (2016) explored transfer and retention of knowledge and found a statistically significant improvement ($p<.05$) for short- and long-term skill between simulation and virtual environment controls. Likewise, mean scores of theoretical tests (i.e., 16.6, $p<.05$) and objective structured clinical examination (i.e., 15.15, $p<.05$) were higher than traditional education controls (i.e., 14.89, 14.71), while means scores were lower for both groups at two months, however, differences were not significant (Soltanimehr et al., 2019). Mixed and no change in knowledge were also noted with no significant differences found in learning approaches for topics (Marei, 2017). Moreover, Farra et al. (2019) found mixed effects and no evidence to suggest a linear relationship between any variables and learning style and no significant difference of knowledge between the VSR and the web-based control. Feng et al. (2013) reported a small overall effect (0.24) in favor of virtual learning environments on knowledge; while Fogg et al. (2013) ANOVA results showed learning style revealed no significant differences to learning.

Level 3 Behavior

Nine studies explored behavior, clinical performance, or intent to change behavior. When measured, eight (89%) reported improvement and one no change in behavior. For the studies that measured behavior, they did so in the clinical environment and found significant performance improvements using metrics such as, time, precision, correctness, efficiency, emergency preparation, diagnosis to treatment, and clinical score (Bartlett et al., 2020; Berg & Steinsbekk, 2020; Farra et al., 2019; Feng et al., 2013; Kang et al., 2020; Liaw et al., 2015; Rutherford-Hemming et al., 2016). Tschannen et al. (2018) found significantly higher post-test scores for application to practice and intend to change behaviors for VRS. Soltanimehr et al. (2019) found no effect on behavior as measured through a clinical score (p.072) between virtual and traditional learning.

Breadth and Depth

Breadth and depth refers to overall span-scope and degree-amount of knowledge (Alavi & Leidner, 2001; Coker et al., 2017; Neuhaus et al., 2006). Taken comprehensively, this literature base demonstrates breadth based on multiple levels of evidence and outcomes. While, all studies explored the impact of VR or screen-based simulation related modalities, the educational development, delivery, and evaluation methods used were varied. Composition and use of intervention and control groups was mixed. Healthcare groups represented here show minimal differentiation and consideration for learner roles and social context (i.e., academic, health system settings). The focal point of this review was nursing, but few studies in nursing education and professional development were found that focus on VR, so additional studies were included from other health-related fields (i.e., dentistry, medicine, and pharmacy) to add breadth to this review.

The reviewed literature has minimal depth due to the heterogeneity of participants and settings that limit generalizability. Students rather than healthcare workers or nurses were often study subjects. As a result, findings on VR and screen-based simulation might not apply to proficient and expert level clinicians. The literature also lacks higher-level outcome measures, such as behavior change or organizational impact. These outcomes are necessary for nursing professional development (NPD) practitioners to generate stakeholder support and to demonstrate the value of professional development in large health systems (Harper et al., 2022; Harper et al., 2016). Lastly, most studies did not incorporate or link theoretical concepts or models to the development, delivery, and evaluation phases which have implications for effectiveness and applicability in practice.

Discussion

Results of this integrative review suggested that most of the evidence (88%) related to VR and screen-based simulation outcomes validated this approach as an effective option for healthcare education and nursing professional development. This review found primarily positive outcomes of use, as evidenced by an increase or improvement in reaction (satisfaction, attitude, perception, and confidence) at 76%, knowledge or skill acquisition 73%, and behavior change 89% of the time. The remaining 12% of studies either did not report or did not find differences between the modalities studied. Given the diversity of modalities under the umbrella of VR, the overall body of evidence might be helpful to educators, administrators, and policymakers to plan integration of VR and virtual environment strategies into health system settings infrastructures.

Limitations

Considerable discrepancy was found within the nomenclature and differentiation of the virtual environment, virtual simulation, VR, screen-based simulation, augmented reality, and mixed reality being used interchangeably with VR (Foronda et al., 2020; Kardong-Edgren et al., 2019; Padilha et al., 2019; Society for Simulation in Healthcare, 2020). This inconsistency made a distinctly VR review a challenging undertaking. Published research has not advanced to align with definitions offered currently by the Healthcare Simulation Dictionary (Lioce et al., 2020). Combined with the novelness of VR and the concomitant dearth of research, this lack of standardized language further limited selection of studies for this review (Farra et al., 2019; Yu & Mann, 2021).

Consistent with other reviews, the evidence synthesized here was limited to a multitude of incomparable learning evaluation methods and the lack of a theoretical foundation in the educational design (Foronda et al., 2020; Ross et al., 2022; Horsley et al., 2018; Shin et al., 2019). Studies were not examined for alignment with quality developmental metrics based on the International Association for Clinical Simulation and Learning (INACSL) (Becker et al., 2020; INACSL, 2016). Studies with non-experimental designs were also a limitation of the review that could be strengthened with a comparison or multiple pre and post-tests and or selection of more experimental studies (Hulley, 2013). Self-reported data used in the studies might have resulted in social conformity, acquiescence bias, and social desirability response bias and might not reflect actual learning outcomes (Shadish et al., 2002). Other threats included nonprobability sampling, instrumentation, and lack of validity and reliability. A few studies conducted pilot tests or modified validated tools, but did not retest for construct validity.

Implications for Practice and Research

The results of this integrative review and the novelty of VR and screen-based simulation lead to several recommendations and practice implications for NPD practitioners, academic nurse educators, and simulationists. First, providing a theoretical and foundational basis through the incorporation of nursing and educational theory, Bloom's (1956) taxonomy, the NPD scope and standards (Harper & Maloney 2022), and Kirkpatrick's (1996) evaluation levels into the structure of the research and educational design will contribute to a more cohesive body of knowledge. Second, more diverse sample pools inclusive of registered nurses and healthcare workers are needed to determine best practice standards and consistent evaluation indicators. Third, organizational and patient outcome measurement, both in practice and in research, is needed to justify resource allocation for VR and to demonstrate NPD value. Fourth, health disparities were only considered in two studies, but should be prioritized to ensure diversity, equity, and inclusive educational practices (Fogg et al., 2013; Marei et al., 2017). Lastly, reporting guidelines for simulation-based research should be considered in future research (Horsley et al., 2018).

Conclusions

VR is a relatively new, but promising innovative modality in NPD. Active learning formats like VR and screen-based simulation that incorporate learner-paced, interactive, feedback-driven, immersive, and collaborative elements have encouraging potential for higher level learning outcomes for registered nurses in practice. However, further development and research on VR modalities and consistency in naming conventions and use are warranted to validate healthcare impact and efficacy (Joda et al., 2019; Kyaw et al., 2019; ONeill et al., 2018; Ramirez, 2018; Rasmussen et al., 2014; Suppan et al., 2020; Yu & Mann, 2021). This review was limited by available VR literature needed for a more meaningful synthesis, indicative of the necessity for more robust studies in healthcare settings.

Table 1

Study Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
• One keyword from Boolean operator found in article title, abstract, or keywords • Research articles levels I-VII • Crowe Critical Appraisal Tool Form (CCAT) quality review score of ≥ 35 • Healthcare and clinical settings • English language, adult subjects • Published, 2008 - 2021	• Records that do not meet Boolean operator strategies • Development, theoretical, or instrument articles • Unpublished works or dissertations • Articles with incomplete outcome data, instrument description, or applicability to healthcare settings

Table 2

Integrative Review Articles

1 Aebersold et al., 2012
2 Alvarez et al., 2011
3 Bakhos et al., 2020
4 Bartlett et al., 2020
5 Berg & Steinsbekk, 2020
6 Botezatu et al., 2010
7 Dubovsky et al., 2017
8 Farra et al., 2019
9 Feng et al., 2013
10 Fogg et al., 2013
11 Georg & Zary, 2014
12 Kang et al., 2020
13 Kohan et al., 2017
14 Liaw et al., 2015
15 Makransky & Lilleholt, 2018
16 Marei et al., 2017
17 Padilha et al., 2019
18 Pilieci et al., 2018
19 Rutherford-Hemming et al., 2016
20 Soltanimehr et al., 2019
21 Tenorio et al., 2020
22 Tran et al., 2020
23 Tschannen et al., 2018
24 Watari et al., 2020
25 Wong et al., 2016

Table 3

Virtual Reality and Screen-based Simulation Outcomes Synthesis

Symbols: ↑, ↓, —, NE, NR, ✓	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
Level #1 Reaction (satisfaction, confidence, perception, attitudes)	↑	↑	↑		↑		↑	—			↑	↑	↓	↑	↑		↑	↑↓			↑	↑	↑		— ↑
Level #2 Learning (knowledge acquisition)		↑				↑		—	—	—		↑		↑		↑↓	↑	↑	↑	↑	↑		↑	↑	
Level #3 Behavior (skill, competency, performance)				↑	↑			↑	↑			↑		↑					↑	—			↑		
Level #4 Results (patient outcomes)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Improvements offered (enhance experience)	✓	✓	✓		✓		✓		✓	✓	✓		✓	✓	✓			✓			✓	✓	✓		
Theoretical Model								✓		✓	✓				✓							✓			

*Learning levels (1-4) adapted from Kirkpatrick Evaluation Model and article numbers referenced in Table 2

SYMBOL KEY

↑ = Increased, ↓ = Decreased, — = No Change, NE = Not Examined, NR = Not Reported, ✓ = applicable or present

Table 4

Virtual Simulation Types Synthesis

↑, ↓, —, NE, NR, ✓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
VR Immersive			✓ III	✓ III	✓ II		✓ IV								✓ III										
VR Sim/Patient	✓ IV	✓ VI				✓ II		✓ IV				✓ IV		✓ II		✓ II	✓ II		✓ II		✓ III	✓ VI	✓ III	✓ III	✓ VI
Mixed VR Environments		✓							✓ I	✓ VI	✓ IV		✓ VI			✓		✓ II	✓	✓ III		✓	✓		✓

*Article numbers referenced in Table 2

SYMBOL KEY

✓ = applicable or studied, ✓ = level three outcomes, I-VII = level of evidence

Table 5

Levels of Evidence Synthesis

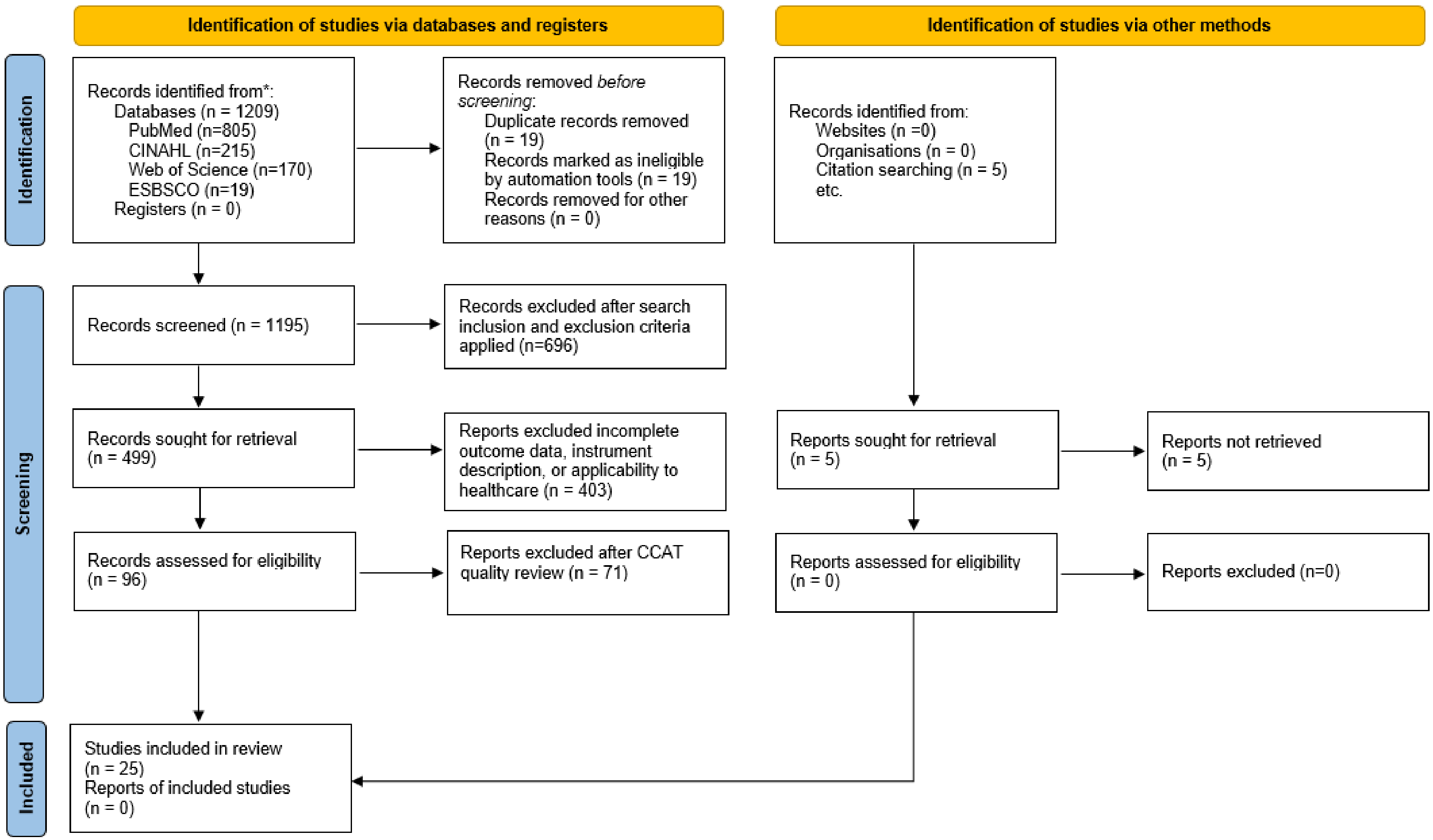
Symbol: X	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
Level I: Systematic review or meta-analysis									X																
Level II: Randomized controlled trial					X	X								X		X	X	X	X						
Level III: Controlled trial no randomization			X	X											X					X	X		X	X	
Level IV: Case-control or cohort study	X						X	X			X	X													
Level V: Systematic review of qualitative or descriptive studies																									
Level VI: Qualitative or descriptive study, CPG, Lit Review, QI or EBP project		X								X			X									X			X
Level VII: Expert opinion																									

* Article numbers referenced in Table 2

Symbol Key

X = Level of Evidence

Figure 1 PRISMA Flow Diagram



Note: © PRISMA Figure (Page et al., 2021)

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Chapter Three: Nurse Knowledge and Behavior, C'*difficile* (Second Manuscript)

Effect of a Virtual Reality Simulation Modality on Registered Nurse Knowledge and Behavior Related to C'*difficile* Prevention: An Experimental, Randomized Controlled Trial Study

Abstract

Background. Virtual reality simulation (VRS) has emerged as an educational methodology in nursing professional development.

Methods. An experimental, randomized control trial was conducted with a sample of clinical registered nurses to compare effectiveness of VRS and traditional education on knowledge and behavior related to C'*difficile* prevention.

Results. No significant differences were found in the effectiveness of the two modalities. The effect size for knowledge (d=.3), may be sufficient to generate interest with group differences in larger groups. Additionally, pre-test scores impacted change in knowledge and behavior scores. A strong negative relationship between pre-test scores and change in knowledge and behavior scores showed that the lower the pretest score the higher the change in knowledge or behavior scores.

Conclusion. The current experimental study found that VRS was a viable educational delivery modality compared to traditional approaches for healthcare education and NPD.

Background

Effective educational delivery requires nursing professional development (NPD) practitioners to engage registered nurses (RNs) to address rising healthcare-associated infections. Behavior change must result from educational activities to prevent hospital-acquired infections. Virtual reality (VR) is defined as a computer-generated learning environment based on presence and immersion, and 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).

Reality is the world we live in and experience with our senses. Technology provides a continuum from reality, to augmented reality (AR), VR, mixed reality, augmented virtuality, to virtuality (Farshid et al., 2018). VR is a three dimensional (3D) computer-generated representation of the actual world and AR overlays information or data on top of the real world through use of an application (Loice et al., 2020). Mixed reality is a hybrid combination of virtual and physical simulation in practice, while augmented virtuality involves practicing real scenarios and virtuality uses images or 3D models (Farshid et al., 2018: Lioce et al., 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 may 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 set-up or scenarios range from $3,000-$15,000. Additional operational costs are determined by number of users (Pottle, 2019).

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

A focus of education in healthcare has been Clostridioides difficile or C. *difficile* (CDI), a bacterium germ that can cause diarrhea. Symptoms range from diarrhea to life-threatening damages to the colon and other organs, up to death. Incidence rate of CDI in the United States is 121.2 cases per 100,000 persons (CDC, 2019). CDI related costs per case are estimated to be between $11,000-17,260 (Scott et al, 2019). CDI preventative measures in healthcare settings have included avoiding unnecessary use of antibiotics, hand hygiene, contact precautions, and thorough high-touch environmental cleaning (Nielsen et al., 2019). Educational interventions that address knowledge and behavior gaps of healthcare workers in these areas has shown effectiveness in reducing CDI incidence (Finnimore et al., 2023; Kamkar, 2017: Read, 2020). Patient outcome data at the study site illustrated that multiple units were underperforming when compared to the standardized infection ratio (SIR) for CDI and traditional educational approaches were not filling the professional practice gaps identified by nursing.

Research has demonstrated positive learning outcomes with VR use (Joda et al., 2019; Kyaw et al., 2019; Lohre et al., 2020; ONeill et al., 2018; Yu & Mann, 2021), with comparisons 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 a lack of 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). Future VR intervention studies need to be conducted with 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 registered nurse (RN) knowledge and behavior related to C'*difficile* prevention. The first aim tested the effect of the delivery format on knowledge and hypothesized that VRS would result in greater knowledge gain than traditional education. The second aim tested the effect of the delivery format on behavior change/performance and hypothesized that behavior change would be greater with VRS than traditional education.

Conceptual Frameworks

The NPD Practice Model was used to frame the structures and processes of this study (Harper & Maloney, 2022). Inputs consist of 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 which lead to practice change (Harper & Maloney, 2022).

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 randomized controlled trial (RCT) with two groups compared the effect of VR to traditional education modalities on RN knowledge and behavior. Screen-based VRS, which was accessible and configured 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 cycle. The control group participated in traditional education.

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). The sample size needed was 41 for each group, calculated by Statacorp 17 LLC (STATA).

Setting and Participants

This study was conducted in a large multi-site, Magnet® designated hospital system with approximately 4400 RNs in the nursing workforce, with an average of 50 RNs per inpatient unit. RNs from six adult acute care units at the two largest inpatient sites were selected as the sample pool, based on patient populations and infection risk. These six units were matched into three pairs based on the patient population. Finally, one pair of units was randomly selected, with one unit designated to receive the VRS intervention. The RNs on the other unit received traditional education and served as the control group.

Recruitment and Study Procedures

Inclusion criteria for RNs on the two identified units included full-time status and ability to complete the study protocol. RNs on leave of absence or vacation during the pre-test, intervention, or post-tests were excluded. Resource and float nurses were excluded due to multiple unit exposure and interaction with the invention and control units.

Eligible participants were identified through the LMS and unit leadership for the two units. Participants received an email link to login to the LMS and access the study purpose, the informed consent, and directions to complete the education and testing. Staff huddles were also disseminated to encourage participation and completion of study protocol. Additionally, discussions were held with unit leaders to ensure adequate time to complete the education and study requirements. The study was approved by the study site Institutional Review Board and adhered to ethical research principles.

Data Collection/Instruments

Participants were allowed 30 days to complete the education. In addition to demographic information, knowledge was assessed using the Cognitive, Affective, and Psychomotor Perceived (CAP-9) Learning Scale (Rovai et al., 2009). This self-report instrument used a Likert-type scale to measure perceived learning with higher scores reflecting higher perceptions of the knowledge. Construct validity was explored through a confirmatory factor analysis, where 3-factors accounted for 66.75% of variance. Internal consistency was assessed through Cronbach alpha =.79. Additionally, a 10-item multiple choice, researcher developed knowledge assessment was administered. Equivalent formats were used for each group, with different pre and post-test 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 the CAP learning scale with items measuring learners' perceived ability and intent to perform the clinical skills. Additionally, a researcher-developed clinical scenario score 0-10 was used as a behavioral metric. The clinical scenario score was tested with a small subgroup of 10 clinical nurses and content validity tested by four subject matter experts and educational experts. The scenario took learners approximately ten minutes to complete and was automatically scored in the LMS. Scores from the CAP were self-reported and the researcher-developed tools were a measure of actual knowledge and behavior so scores from the latter were used in statistical analysis. To control for confounding variables, unlicensed staff on both units also received traditional education but were not part of 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 showed patterns and trends. Levine's test of homogeneity of variances and Shapiro-Wilk for normality were used. A hypothesis test and confidence interval (CI) approach was used for continuous variables (Rosner, 2015). Simple comparisons using independent *t*-tests tested knowledge and behavior change between intervention and control units, with Cohen d for effect size. Additional regression analyses explored the relationships of selected demographic and professional characteristics to changes in knowledge and behavior within each education delivery method. To explore whether pre-intervention levels of knowledge and behavior impacted the potential for change, a less than adequate pre-test score covariate (i.e., <80%) was added in the change in knowledge and behavior regression models, to remove higher pre-test scoring participants (i.e., >80%). Correlations between pairs of continuously scaled predictor variables explored significant relationships and collinearity in regression analysis.

Results

Sample Description

Eighty-four medical-surgical RNs participated in the study, with 44 in the VR intervention group and 40 in the control group. As shown in Table 1, the overall sample was predominately female (80.95%), with a mean age of 39.25. Most of the participants held a BSN degree (63.1%) and were not certified (65.48%). Half of the participants identified as Asian (50%) and 27.38% as White.

Primary Findings

Aim 1: Changes in Knowledge

Independent *t*-tests with equal variances indicated that there was no significant differences (t=1.4, p =.16) for change in knowledge between group means ± the standard deviation for the VR intervention (1.3 ± 1.39) and TE control (1.75 ± 1.58). Cohen's *d* effect size was small at d=.3.

Aim 2: Changes in Behavior

For change in behavior, there was no significant difference (t=.67, p =.5) between group means for the VR intervention (.205 ± .84) and TE control (.325 ± .8). Cohen's *d* effect size was very small at d=.15. See Table 2 for scores on outcome measures and *t*-test results.

Additional Findings

Four regression models were explored, two for change in knowledge (Models 1, 2) and two for change in behavior (Models 3, 4). To determine whether improvement was related to pre-intervention levels of knowledge and behavior, less than adequate pre-test knowledge and pre-test behavior (i.e., scores <80%) were added. Table 2 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) had three significant predictors of low pre-test knowledge (p=.001), gender (p=.024), and specialty certification (p=.004) and Model 2 (TE group) one significant predictor of pre-test knowledge (p=.004). For change in behavior Model 4 was statistically significant (Control p=.023).

Discussion

Results of this RCT showed no significant differences in the approaches for knowledge or behavior. The effect size for knowledge (d=.3), may be sufficient to generate interest with group differences potentially significant in large groups in comparison to the small sample used in this study. Additionally, pre-test scores impacted change in knowledge and behavior scores. A strong negative relationship between pre-test scores and change in knowledge and behavior scores showed that the lower the pretest score the higher the change in knowledge or behavior scores. These results were consistent with other studies in nursing and other healthcare fields (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

This study included a small sample size resulting in limited generalizability. Additionally, the educational intervention and grouping by units might have created inequities. Response bias may have existed for self-reported measures that did not align with the researcher developed knowledge and behavioral measures. Finally, cross-over or competing C*'difficile* education outside of the study, may have potentially under or overestimated the effect of the intervention.

Implications for Education, NPD Practice, and Research

The effectiveness of the VRS and TE approaches guides key stakeholders and policymakers in making decisions about the use of VR. NPD practitioners, academic nurse educators, and simulationists are in prime positions to use VRS in practice and study its impact compared to current approaches related to learner and organizational outcomes in a variety of settings. VR offers individualized active learning, but nurses will still need additional support to adjust to changing practice and learning environments (Nair et al, 2021). Use of standardized terms for VR through the use of the Healthcare Simulation Dictionary (Lioce et al., 2020) is strongly encouraged to advance and generate comparative outcomes in practice and research.

In consideration of the results of the recent NPD value analysis study finding increases in C'*difficile* rates across organizations with higher NPD staff (Harper et al., 2022), an immersive VR modality could be used with nursing and unlicensed staff to evaluate efficacy related to approaches to impact practice outcomes. As an extension of the current study, the patient outcome impact on C'*difficile* rates is currently being explored and will be reported elsewhere. Next steps will include a financial analysis of approaches to drive decision-making related to educational infrastructure and resource allocation to measure the return on investment for NPD activities related to known costs of C'*difficile* outcomes (Opperman et al., 2022a, 2022b).

Conclusions

VRS is an exciting new modality in NPD. The current experimental study found that VRS was a viable educational delivery modality compared to traditional approaches for healthcare education and NPD. Experiential VRS approaches that facilitate learning as evidenced by higher level learning outcomes that can be exported back in the environment was the actualized goal in this study. Exploration of optimal patient outcomes will be the next step to explore.

TABLE 1	**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			
Whites	23(27.38)	11(25)	12(30)
Asian	42(50)	25(56.82)	17(42.5)
Blacks	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	53(63.10)	25(56.82)	28(70)
Master/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: Abbreviations – N or n = number of participants: Prof = professional degree			

TABLE 2	Scores on Outcome Measures, *t*-tests, Regression Models				
Measure	**Mean (SD)**	***t* score (DF)**	**CI**	**p value**	**Effect size***
Change in Knowledge					
Intervention	1.3 (1.39)	1.4 (82)	.873, 1.718	0.16	.3
Control	1.75 (1.58)		1.244, 2.256		
Change in Behavior					
Intervention	.205 (.84)	0.67(82)	-.039, .448	0.5	.15
Control	.325 (.8)		.055, .595		

Note: *effect size Cohen’s d; Abbreviations: SD = Standard deviation, DF = Degrees of freedom , CI = Confidence Interval

Measure	**Variables**	**Standardized Coefficient**	**VIF**	**95% CI**	**p value**	**r-squared**
Change in Knowledge						
Intervention	Model 1		1.18		**<.001***	.427
	Low pre-test	.472	1.21	.55, 2.11	**.001***	
	Years experience	.109	1.1	-.026, .063	.408	
	Gender	-.331	1.27	-2.093, .16	**.024***	
	Race	.133	1.14	-.196, .583	.321	
	Highest Degree	-.204	1.11	-.936, .122	.128	
	Specialty Cert.	.004	1.27	.416, 2.007	**.004***	
Control	Model 2		1.14		**.045***	.309
	Low pre-test	.488.	1.22	.52, 2.59	**.004***	
	Years experience	-.088	1.16	-.063, .036	.577	
	Gender	-.044	1.07	-1.43, 1.072	.773	
	Race	.098	1.09	-.297, .574	.521	
	Highest Degree	-.075	1.10	-.967, .590	.626	
	Specialty Cert.	-.074	1.23	-1.401, .882	.646	
Change in Behavior						
Intervention	Model 3		1.13		.097	.241
	Low pre-test	.363	1.03	.216, 2.072	**.017***	
	Years experience	.106	1.04	-.019, .04	.473	
	Gender	-.028	1.19	-.677, .568	.860	
	Race	-.024	1.16	-.281, .241	.876	
	Highest Degree	-.306	1.12	-.705, .001	.051	
	Specialty Cert.	.137	1.23	-.299, .74	.395	
Control	Model 4		1.10		**.023***	.344
	Low pre-test	.533	1.09	.59, 2.099	**.001***	
	Years experience	-.041	1.15	-.029, .022	.783	
	Gender	.113	1.07	-.404, .899	.445	
	Race	.208	1.03	-.063, .377	.156	
	Highest Degree	.014	1.16	-.398, .435	.929	
	Specialty Cert.	.104	1.12	-.374, .761	.493	

Note: bolded * p value significant < 0.05; Abbreviations: VIF = Variance inflation factor

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Chapter Four: C'*difficile Rates* and Return on Investment (Third Manuscript)

Impact of a Virtual Reality Simulation Modality Compared to Traditional Education on *C'difficile* Rates: A Randomized Controlled Trial and Return on Investment Analysis

Abstract

Background: Virtual reality simulation (VRS) is an innovative modality in nursing professional development that has the potential to impact patient outcomes.

Method: An experimental randomized controlled trial (RCT) design was performed with registered nurses on two inpatient units in a large academic health system to evaluate the impact of VRS compared to traditional education on C'*difficile* rates. Return on investment of nursing professional development activities was also measured to support decision-making and resource allocation.

Results: C'*difficile* rates were significantly lower for both groups for the 3-month post intervention period as compared to the 10-month period pre-intervention. Financial analysis showed a return on investment for both modalities, with VRS having higher yields over time.

Conclusions: Findings illustrated that VRS is an effective instructional method.

Background

The *Centers for Medicare and Medicaid Services* (CMS) publishes data to promote accountable care and The *National Healthcare Safety Network,* part of the *Center for Disease Control and Prevention* (CDC), tracks healthcare-associated infections (HAIs) to support evidence-based approaches (CDC, 2019; CMS, 2021). The *World Health Organization* (WHO) and CDC provide guidelines and recommendations for infection prevention such as, targeted, innovative education and training approaches for healthcare workers (CDC, 2019, WHO, 2021).

HAIs are correlated with morbidity and mortality in the United States (U.S.) (CDC, 2021). Four percent of patients in the U.S. and 10% worldwide are diagnosed with an infection while in the hospital (CDC, 2017; WHO, 2021). HAIs have increased during the COVID pandemic despite current infection prevention control practices and educational approaches (CDC, 2021). Since HAIs and emerging infectious diseases are prevalent, innovative infection prevention education is a priority for the U.S. healthcare workforce (Burnett, 2018).

Health system C'*difficile* infection rates at the study site were above the benchmark, indicating underperformance for this HAI when compared to the standardized infection ratio (SIR). This ratio is calculated by dividing actual by predicted HAIs. A goal of <1 would mean performance is better than expected. *C'difficile* causes severe diarrhea and colitis and is commonly seen in patients receiving antibiotics (CDC, 2023). Nearly, 1 out of every 6 patients are re-infected within 2-8 weeks and 1 out of 11 people over the age 65 diagnosed with *C'difficile* die within 1 month (CDC, 2023). *C'difficile* costs range from $11,000-17,260 per case (Scott et al, 2019). These known costs can be used to measure the impact of nursing professional development (NPD) initiatives to drive decision-making and resource allocation (Opperman et al., 2022a; Opperman et al., 2022b)

Registered nurses (RNs) in inpatient acute settings have substantial patient contact and perform vital roles in *C'difficile* prevention by ensuring that standard infection prevention and transmission safeguards are followed. Standard precautions for all patients include personal protective equipment, hand hygiene, and safe handling and disposal (CDC, 2021). Transmission safeguards represent additional isolation precautions taken when patients are infected. Effectiveness of following safeguards is captured through nursing-sensitive indicators and can be used to measure the impact of nursing and unlicensed staff activities related to incidence.

Innovative approaches such as virtual reality (VR) may provide a viable approach for infection prevention education. Modalities within the broad umbrella of VR range from extended reality, virtual environment, virtual reality simulation (VRS), virtual simulation, augmented reality, to mixed reality (Foronda et al., 2020; Kardong-Edgren et al., 2019; Shin et al., 2019, Society for Simulation in Healthcare [SSH], 2020). VR uses 3-D head-mounted displays where an immersive virtual world is projected into a wearable device (SSH, 2020). VRS is a 3-D, screen-based environment that uses a variety of interfaces such as computer keyboards/mouse, voice and motion recognition, and avatars, to create learning spaces that resemble practice settings or procedures (Lioce et al., 2020; Ross et al., 2022; SSH, 2020).

Purpose/Aim

The purpose of this study was to compare the impact of VRS to traditional education (i.e., asynchronous lecture module), on C'*difficile* rates. The first aim was to compare the C'*difficile* rates for the control group and the intervention group after delivering the two educational modalities. The standardized infection ratio (SIRs) for C'*difficile* was hypothesized to be lower for the VRS group compared to the traditional education group. The second aim was to explore the return on investment (ROI) of these two educational delivery methods.

Methods

Approach

An experimental randomized controlled trial (RCT) design with two groups was used to explore the impact of VRS compared to traditional education on C'*difficile* rates. Independent variables were the two educational modalities, differentiated by VRS (active) verse traditional education (passive) delivery approaches. Demographic data were also collected. The dependent or response variable was the C'*difficile* rate per 10,000 patient days measured pre- and post-intervention on the two units. The intervention group received the VRS education modality and the control group received traditional education. Sample size recommendations for each group was 41 based on Statacorp 17 LLC (STATA).

Study Setting and Participants

The study was conducted at an academic health system, ranked in the Top 5 according to the *U.S. News & World Report* (*2022-2023)*, offering comprehensive and advanced health care. The health system has approximately 4,400 RNs in the workforce. The study took place at the largest inpatient site with approximately 520 inpatient beds and an average of 60 RNs per unit. This site holds American Nurses Credentialing Center's (ANCC) Magnet Designation® and Practice Transition Accreditation Program (PTAP) Distinction for newly licensed nurses.

Participants were RNs selected from six adult acute care units. These six units, consisting of two medical intensive care units, two progressive care units, and two surgical units, were matched to create three pairs of units. One pair of matched units was randomly selected for participation in the study and assigned to either the VRS or the traditional education group. RNs from the randomly selected units comprised the final participant sample.

Recruitment and Study Procedures

Fulltime equivalent RNs employed on the units at the time of the study and able to complete the study protocol met the inclusion criteria. RNs on leave or vacation during the pre- or post-test times were excluded. Resource or float RNs were also excluded due to the potential interaction with both invention and control groups.

Nurses on the two randomly selected units were recruited by email, staff huddles, and word of mouth by unit managers, assistant nurse managers, NPD practitioners, and the clinical nurse specialist. Due to the increased infection rates, all staff on the two units were required to complete the education assigned in the learning management system, regardless of study participation. Participants who signed the informed consent were enrolled in the study and their respective pre- and post-test scores were collected for study purposes. The study adhered to ethical research principles and was approved by the study site Institutional Review Board.

Instruments/Data Collection

Participants in each group had 30 days to complete the assigned education. The VRS group used a computer screen, keyboard, mouse, voice and text recognition, and a first-person avatar to maneuver through the learning scenario. The learning space was a realistic patient room with a live patient, student nurse, and the RN learner. The traditional education group participated in an asynchronous, learner-paced computer-based module with voiceover to resemble a lecture. Both formats had the same objectives, were developed by NPD team members and an infection prevention specialist, and were accessible in the health system learning management system. Unlicensed staff on both units also received traditional education but were not included in the study sample.

In addition to collecting demographic information, knowledge and behavior changes were obtained through a validated tool (Rovai et al., 2009) and two researcher-developed tools. C'*difficile* outcome data were collected from the health system dashboard, based on the National Healthcare Safety Network guidelines (NHSN, 2023). For the dashboards, inpatient hospital-acquired C'*difficile* rates were identified in by a positive PCR test on or after hospital day four, followed by a positive antigen test. The organization converted to this two-step verification process in November 2021, which resulted in a reduction of identifiable cases. Data published on the dashboard reflected cases that met the definition of healthcare facility-onset (i.e. inpatient hospital stay), meaning that the patient tested positive for C'*difficile* on or after hospital day four with day one being admission (NHSN, 2023). Rates were calculated by infections divided by patient days.

Data Analysis

Descriptive statistics were used to summarize demographics. Means, standard deviations, frequencies, and/or percentages were used to summarize the groups. Knowledge and behavior change were analyzed at the individual level and submitted for publication elsewhere. C'*difficile* rates, as calculated by the organization, were reported at the unit level. MedCalc statistical software was used for rate comparisons. Incidence rate in the two groups and the difference in rates were analyzed using the Poisson distribution, a 95% confidence interval, and an associated p-value. For rate differences, statistical significance was set at $p < 0.05$. Additionally, a rate ratio not equal to 1, was considered clinically significant.

Financial analysis of NPD activities was calculated through cost effectiveness, benefit-cost-ratio, and return-on-investment equations (Opperman et al., 2022b) for both the intervention and control groups. Cost effectiveness explored the total costs of each of the learning modalities, divided by the participants to yield the cost per participant. Benefit-cost-ratio evaluated the known costs for one prevented C'*difficile* case (Scott et al., 2019) divided by total costs of the NPD activity. Return-on-investment factored in the known outcome costs of one C'*difficile* case minus the total costs of the NPD activity, divided by the total NPD activity costs multiplied by 100. Two scenarios are provided in the results section to illustrate the economic impact of NPD study activities and temporal effects, or amortization, to inform decision-making and resource allocation.

Results

Demographics

The VRS intervention and traditional education control group samples were 44 and 40 respectively, with a total study sample of 84 medical-surgical RNs. The VRS group was predominately female (79.55%), with a mean age of 38.98. Over half (56.82%) of the participants held a BSN degree, (31.82%) held a Master's degree or higher, and (40.9%) were certified. Over half (56.82%) the participants identified as Asian and (25%) as White. The traditional education group was predominately female (82.5%), with a mean age of 39.55. Nearly three-fourths (70%), of the participants held a BSN degree with (22.5%) a Master's degree or higher, and (27.5%) were certified. Less than half (42.5%) of the participants identified as Asian and (30%) as White. See Table 1 for additional participant sample details. There were no statistically significant relationships between categorical or continuous variables.

Patient Data and C'*Difficile* Rates

Patient admissions at the time of the study by group (intervention, control) were (78, 106) pre-intervention in September 2022, (91, 82) during-intervention in October 2022, and (88, 91) post-intervention in November 2022. Patient days for the same time periods and groups were (794, 790) pre-intervention, (802, 814) during-intervention, and (818, 837) post-intervention. Data illustrated comparable C'*difficile* risk based on patient flow. C'*difficile* rates for the intervention and control units at the 1-month pre-intervention period was (12.53, 0). However, C'*difficile* rates for the intervention and control units were (3.87, 3.89) for the previous 10 months, (2.11, 2.13) 6 months, and (3.12, 3.15) 3 months prior to study implementation. Dividing the *C'difficile* data into two segments before and after the 2-step verification process change, December 2020-November 2021 and December 2021-November 2022, yielded intervention group rates of (8.67, 3.21) compared to (6.61, 3.21) for the control group.

C'*difficile* rates for the intervention and control units at 1-, 2-, and 3-months post-intervention periods were 0. See Figure 1 for C'*difficile* rates and times.

Aim 1: C'*difficile Rate Comparisons*

As shown in Table 2, Poisson distributions for C'*difficile* rate comparisons indicated a statistically significant difference between group rates (i.e., infections/patient days) for the intervention (12.53) and control (0) groups at the pre-intervention period, one month before the intervention (p =.0003) and three months before (p =.0004). No statistically significant C'*difficile* rate differences were found between and within the intervention and control groups 1-, 2- or 3-months post-intervention periods. The control group had no statistically significant C'*difficile* rate differences between 1-month pre-intervention to 1-month post-intervention. However, the intervention group had significantly lower rates for these intervals (p =.0003). For pre-intervention periods (10, 6, 4 months) compared to longer post-intervention periods (3 months), there were statistically significantly lower C'*difficile* rate differences between the 10-month pre-intervention and 3-month post-intervention for both the intervention and control groups (p = .0455). No statistically significant rate or incidence rate ratio differences were found within the intervention and control groups before or after the 2-step verification process change.

Aim #2 Economic Impact of NPD Activities

Figure 2 shows the financial comparison between control and intervention groups. Traditional education yielded a cost of $145 per nurse, a benefit-cost-ratio of 3:1, and ROI of 198%. The VRS showed a cost of $338 per nurse, a 1:1 benefit-cost ratio, and a 16% return on investment. While both modalities produced a positive ROI, the VRS was impacted by the initial investment costs to develop this screen-based immersive learning environment.

To account for upfront costs, an amortized scenario in Figure 3 illustrates the financial comparison with equivalent group numbers if these educational modalities were used again for NPD activities when content updates are needed. Calculations for traditional education yielded the same results as the study scenario above, due to updates of content. The VRS showed a cost of $90 per nurse, 5:1 benefit-cost ratio, and a 378% return on investment. Since, the VRS scenario was already purchased and developed, only moderate costs would be incurred for content changes.

Discussion

Findings from the current study showed some within and between differences using VRS compared to traditional education on C'*difficile*. When comparing longer pre-intervention to longer post-intervention periods to capture trends over time, C'*difficile* rates were significantly lower from pre to post-intervention for both the VRS and traditional education groups. Post-intervention periods of 3-months for both groups yielded a rate of zero. This finding represented the longest trend below benchmark for both groups across the organizational dashboard. Despite not finding statistically significant differences between the two modalities pre- to post-intervention (one month), both educational modalities impacted C'*difficile* rates over longer durations. Financial analysis in the two study scenarios also illustrated a positive ROI to inform resource allocation, curricula planning, and justification for investment in VRS use in practice.

Efficacy of VR approaches (Joda et al., 2019; Kyaw et al., 2019; Lohre et al., 2020; Yu & Mann, 2021, compared to traditional approaches (Bakhos et al., 2020; Berg & Steinsbekk, 2020; Marei et al., 2017) on learner outcomes (Dubovi et al., 2017: Shujuan et al, 2022; Yu et al., 2021), and patient outcomes (Baldwin et al., 2010; Menegueti et al., 2019) are found in the literature. However, these studies are sparse and limited by participant response evaluations and student samples rather than RNs or healthcare workers (Berg & Steinsbekk, 2020; Kang et al., 2020; Padilha et al., 2019; Tran et al., 2020) and inconsistent use of VR and VRS terms (Plotzky et al., 2021). The current study was intended to narrow these gaps. Additionally, researchers have recommended exploring knowledge retention (Suppan et al., 2020), comparative approaches (Alrubaiee et al., 2021; Menegueti et al., 2019), higher level learning outcomes (Desta et al., 2018; Jeihooni et al. 2018), differentiation of learning (Carter et al., 2017; Koo et al., 2016), and beliefs and values that contribute to behavior change (Jeihooni et al., 2018; ONeill et al., 2018; Salem, 2019).

Consistent with other studies, comparative costs between VRS and traditional education, such as lectures, have shown higher initial costs with reductions over time for VRS and fixed costs for traditional education (Dubovi et al., 2017; Farr et al., 2019). Evidence suggests that traditional education is prohibitive based on time, space, and cost (Phillips et al., 2021; Shorey & Ng, 2021). Implementation costs vary by site, modality, participants, software, educators, simulated patients, and administrative support needed. However, returns can yield time and cost savings in training healthcare workers (Liaw et al., 2022; Parham et al., 2019).

The current study was informed by three impact studies. First, the NPD value analysis study findings that showed increased C'*difficile* rates with higher NPD staff levels due to the pandemic (Harper et al., 2022). Since interventions are often delegated to unlicensed staff, results suggested that NPD initiatives should also focus on unlicensed personnel. This was also validated by participant response data at the *Association for Nursing Professional Development 2022 Convention*. Thus, unlicensed staff were provided traditional education in the current study in an effort to yield the greatest impact and to limit intervening variables. Second, Opperman and colleagues (2022a) evaluated studies with educational interventions for clinical professionals that measured pre- and post-intervention outcomes and financial impact. Study design and summary results of the current study found that NPD activities showed a positive impact on outcomes and economics to inform advocating for resources. Third, the current study applied the illustration of NPD value through utilization of the Known Costs of Outcomes to connect to NPD practice and organizational outcomes (Opperman et al., 2022b).

Patient outcomes are essential for NPD leaders to connect to the organizational mission, vision, and values. NPD leaders need core competencies to be effective. The Association for Nursing Professional Development endorsed a study that identified core competencies in executive nursing, business acumen, organizational alignment, communication and relationship building, and NPD practice for leaders with multisite responsibilities (Harper & Maloney, 2022). Application of these core competencies is vital for NPD leaders to empower practitioners and specialists to evaluate the impact of educational programs and infrastructure in alignment with the organizational strategic plan. Stakeholder support of NPD activities will then be strengthened by illustrating patient and learner outcomes.

Limitations

The small sample size in this study limits the generalizability of findings. Grouping by units might have created participant dissatisfaction. For example, some RNs wanted to participate in the VRS. Others who participated in VRS expressed difficulty with this new technology. Moreover, some RNs also suggested the realness of the VRS scenario did not match their experiences using VR headsets that have higher immersion levels and presence in the learning space. VRS was chosen for this study due to the availability of computer hardware and software configuration of computer workstations at the inpatient sites. Additionally, the study was not adequately powered, due to the limited C'*difficile* rate data points collected at the group level. Complexity of the group and time period comparisons suggested the possibility of using a more complex model in future analysis (i.e. interrupted time series). Finally, changes in C*'difficile* surveillance and concurrent education, may have impacted the study results.

Implications for Education, NPD Practice, and Research

NPD practitioners are called to use organizational metrics and patient outcomes to evaluate value and return on investment of NPD activities (Harper et al., 2022; Opperman et al., 2022a; Opperman et al., 2022b). Applying VRS in practice and evaluating its efficacy can inform key stakeholders and policymakers, healthcare administrators, NPD practitioners, academic nurse educators, and simulationists about the use of this modality. Academic nurse educators and NPD practitioners are in prime positions to consider the results of this study for future curricula planning in their respective settings. Readers should consider using definitions offered by the Healthcare Simulation Dictionary (Lioce et al., 2020) to align nomenclature in future research. Cant and Ryan (2013) also provided a comprehensive list of virtual simulation applications with a variety of topics and learner types for educators to use in curricular planning.

Future interventions in place for C'*difficile* prevention at the study site includes the development of a root cause analysis approach when patients are identified with hospital onset; as well as, further exploration of VR programming for all members of the healthcare team. Results of this interdisciplinary process will support identification of professional practice gaps and potential strategies to close gaps. There is not one superior educational method but rather multiple approaches that NPD practitioners and educators can consider, but decisions necessitate evaluation of benefits offered by each approach or technology. Researchers could also consider findings when designing and exploring VRS efficacy in a variety of settings that may generate new knowledge on financially efficient and effective approaches to immerse and engage learners.

Conclusions

This experimental study found that both VRS and traditional education modalities impacted C'*difficile* rates and produced positive economic returns on investment to inform future resource allocation. VRS was impacted by upfront costs, but over time VRS showed greater potential for return on investment than traditional education. Findings illustrated that VRS is a viable instructional method that yields positive return on investment and patient outcomes.

Table 1. Nurse Participant Characteristics and Differences Between Groups

Demographics	**Mean ± standard deviation or n (%)**			
	Overall Sample (N=84)	VR Intervention (n=44)	TE Control (n=40)	*p*
Age	39.25 ± 10.27	38.98 ± 10.06	39.55 ± 10.62	.800[a]
Years of Experience	12.31 ± 9.10	12.03 ± 8.18	12.61 ± 10.12	.773[a]
Gender				.731[b]
Female	68(80.95)	35(79.55)	33(82.50)	
Male	16(19.05)	9(20.45)	7(17.50)	
Race				.585[c]
Whites	23(27.38)	11(25)	12(30)	
Asian	42(50)	25(56.82)	17(42.5)	
Blacks	3(3.57)	1(2.27)	2(5)	
Prefer not say/Other	16(19.05)	7(15.91)	9(22.5)	
Highest Nursing Degree				.473[c]
Bachelor	53(63.10)	25(56.82)	28(70)	
Master/Doctorate/Prof	23(27.38)	14(31.82)	9(22.5)	
Associate	8(9.52)	5(11.36)	3(7.5)	
Specialty Certification				.197[b]
No	55(65.48)	26(59.09)	29(72.50)	
Yes	29(34.52)	18(40.91)	11(27.50)	

Note: **Abbreviations – N or n = number of participants: Prof = professional degree**
[a] *t* tests used to explore differences between groups in continuous variable
[b] Chi square used to explore differences between groups in categorical variable
[c] Fisher exact used for differences between groups in categorical variable with expected frequencies ≤5
[d] There was also no statistically significant relationships between groups in variables

Table 2. C'*difficile* Rate Comparisons									
Group	**Comparison Time**	**Rate**	**Incidence**	**Incidence Rate Difference**	**95% CI Rate Difference**	***p* value**	**Incidence Rate Ratio**	**95% CI Rate Ratio**	***p* value**
Intervention	Pre (1 month) Pre (3 month)	12.53(13) 4.1(4)	.0013 1:769 0.0004 1:2500	.0013 1:769 0.0004 1:2500	.000593, .002007 1:1685, 1:498 0.000008, 0.000792 1:124888, 1:1263	.0003* .0004*			
Control		0, 0	0, 0						
Intervention	Post (1 month) Post (2 months) Post (3 months)	0, 0, 0	0, 0, 0	0	-	-			
Control		0, 0, 0	0, 0, 0						
Intervention	Pre (1 month)	12.53(13)	.0013 1:769	.0013 1:769	.000593, .002007 1:1685, 1:498	.0003*			
	Post (1 month)	0	0						
Control	Pre (1 month)	0	0	0	-	-			
	Post (1 month)	0	0	0					
Intervention	2-step verification change before and after (12 months)	8.67(9)	.0009 1:1111	.0006 1:1667	-.000079, .001279 -1:12666, 1:782	.0833	3	.7487, 17.228	.0923
		3.21(3)	.0003 1:3333						
Control	2-step verification change before and after (12 months)	6.61(7)	.0007 1:1429	.0004 1:2500	-.0002198, .0010198	.2059	2.3333	.5327, 13.9836	.2266
		3.21 (3)	.0003 1:3333						
Intervention	Pre (10 months)	3.87(4)	.0004 1:2500	.0004 1:2500	.000008, .000792 1:124888, 1:1263	**.0455***			
	Pre (6 months)	2.11(2)	.0002 1:5000	.0002 1:5000	.0000242, .0007225 -1:12957, 1:2096	.1573			
	Pre (4 months)	3.12(3)	0.0003 1:3333	0.0003 1:3333	-.0000395, .0006395 -1:25332, 1:1564	.0833			
	Post (3 months)	0	0	0	-	-			
Control	Pre (10 months)	3.89(4)	.0004 1:2500	0004 1:2500	.000008, .000792 1:124888, 1:1263	**.0455***			

	Pre (6 months) Pre (4 months)	2.13(2) 3.15(3)	.0002 1:5000 0.0003 1:3333	.0002 1:5000 0.0003 1:3333	.0000242, .0007225 -1:12957, 1:2096 -.0000395, .0006395 -1:25332, 1:1564	.1573 .0833	
	Post (3 months)	0	0	0	-	-	
Intervention	Pre (3 months)	4.1(4)	.0004 1:2500	0004 1:2500	.000008, .000792 1:124888, 1:1263	**.0455***	
	Post (3 months)	0	0	0	-	-	
Control	Pre (3 months)	0	0	0	-		
	Post (3 months)	0	0	0	-	-	
***Note*: rates rounded in ( ); rate comparisons, denominator is rate and numerator is 10,000 patient days; bolded * *p* value significant < 0.05**							

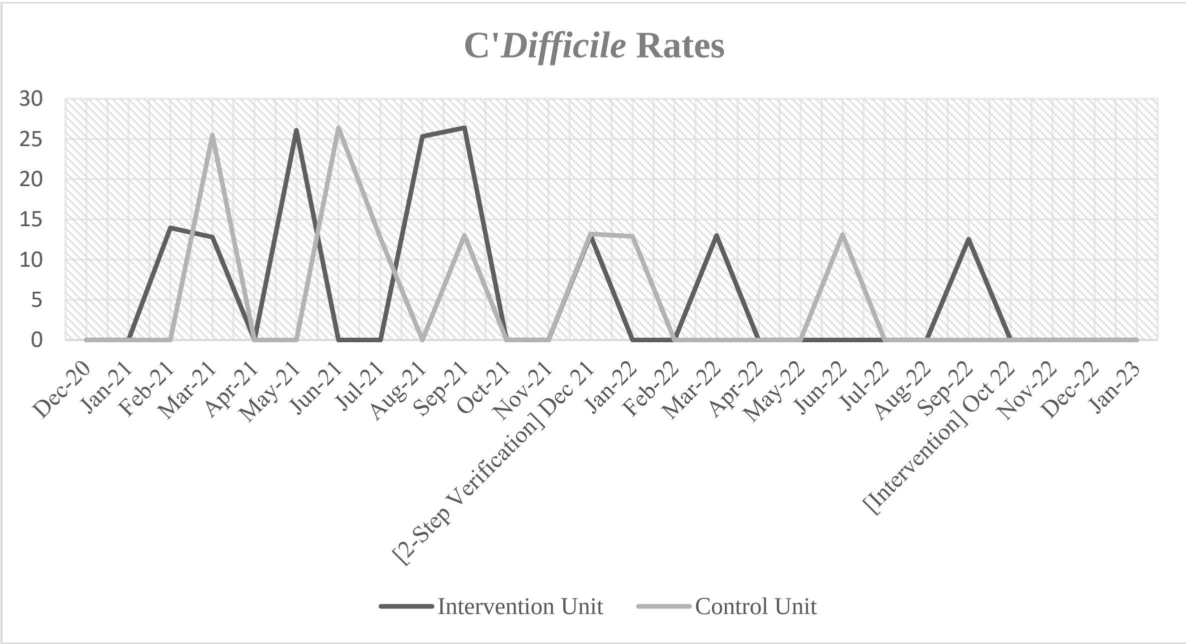

***Figure 1.* C'*difficile* Rates.** Shows the C'*Difficile* rates on study units from December 2020 to January 2023. The two-step verification change in December of 2021 and the 30-day intervention in October 2022 are [ ] for emphasis. Post-implementation rate was zero for both units for 3 months.

Cost Calculations	Traditional Education (Control Group) n=40		Virtual Reality Simulation (Intervention Group) n=44	
C'*difficile* Cost (1 prevented case)	$17,260		$17,260	
Average Nurse Salary	$65/hour x 1 hour x 40 nurses	$2,600	$65/hour x 1 hour x 44 nurses	$2,860
Education Expenses	$80 x 40 hours (develop/deliver)	$3,200	$12,000 (VR develop/deliver)	$12,000
Total Expenses	Nurse Time + Education expenses	$5,800	Nurse Time + Education expenses	$14,860
Cost Effectiveness	$5800/40 nurses = $145/nurse		$14,860/44 nurses = $338/nurse	
Benefit-Cost-Ratio	$17,260/$5,800 = 2.98:1		$17,260/$14,860 = 1.16:1	
Return-on-Investment	$17,260-$5800/$5800 X 100 = 198%		$17,260-$14,860/$14,860 X 100 = 16%	

Figure 2. Study Scenario. Shows the financial analysis calculations (Opperman et al., 2022b) for study groups. C'*difficile* costs from (Scott et al, 2019), other salary data and expenses from the study site. For simplification, cost for prevention of one C'*difficile* case was used for both groups, since post-implementation rates were zero.

Cost Calculations	**Traditional Education (Control Group)**		**Virtual Reality Simulation (Intervention Group)**	
C'*difficile* Cost (1 prevented case)	$17,260.00		$17,260.00	
Average Nurse Salary	$65/hour x 1 hour x 40 nurses	$2,600	$65/hour x 1 hours x 40 nurses	$2,600
Education Expenses	$80 x 40 hours (develop/deliver)	$3,200	Costs amortized (maintenance)	$1,000
Total Expenses	Nurse Time + Education expenses	$5,800	Nurse Time + Education expenses	$3,600
Cost Effectiveness	$5,800/40 nurses = $145/nurse		$3,600/40 nurses = $90/nurse	
Benefit-Cost-Ratio	$17,260/$5,800 = 2.98:1		$17,260/$3,600 = 4.79:1	
Return-on-Investment	$17,260-$5,800/$5,800 X 100 = 198%		$17,260-$3,600/$3,600 X 100 = 379%	

Figure 3. Amortized Scenario. Shows financial analysis calculations (Opperman et al., 2022b) with equivalent group numbers when updates to content are needed. C'*difficile* costs (Scott et al, 2019) based on reduction of one case, other estimated costs specific to study site.

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Chapter Five: Dissertation Summary

Significance of the Study

This integrative review and research illustrate the value of VRS in comparison to traditional education for healthcare education and NPD. From the integrative review, there were gaps in the literature concerning a lack of registered nurses and healthcare workers samples, higher level organizational and patient outcomes, and economic justification of educational modalities. For the research study, there were no statistically significant differences by modality, demonstrating that both VRS and TE offer effective education for RNs. VRS and traditional education modalities impacted nurse knowledge and behavior, C'*difficile* rates, and economic returns to inform future resource allocation, with VRS showing greater potential for return on investment and comparable knowledge and behavior changes pre to post intervention.

Directions for Future Research

This dissertation revealed some directions for future research. Continued research on the efficacy of simulation and virtual reality approaches are vital to validate use in health systems and academic environments (Horsley et al., 2018). Effective educational modalities provide the requisite knowledge for incorporation of learning into practice in health systems. Academic educators and NPD practitioners can consider the current study results for future curricula planning, while researchers could consider findings to continue to generate new knowledge to immerse and engage learners. Implications of these directions could lead to the actualization of higher level outcomes that lead to safe quality patient care and an overall reduction of HAIs, such as C'*difficile* in health systems. Financial analysis of educational modalities could also impact cost of care and NPD activities (Opperman et al., 2022a; Opperman et al., 2022b). Future research has the potential to shape and enrich NPD and nursing practice in health systems.

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