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Clinical Virtual Simulation: A Qualitative Usability Study

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ABSTRACT

Background: Simulation-based training is an important pedagogical approach used in nursing education. Recently, academic institutions have begun integrating virtual simulation technologies into nursing curricula. There is an increasing need to explore nursing students' and faculty members' usability experiences toward virtual simulations.

Research Question: What are the usability experiences of nursing students and faculty who trialed an in-house designed and developed clinical virtual simulation used to demonstrate a wound dressing change?

Methods: Seven participants were recruited. Primary data was collected using a Think Aloud approach followed by individual interviews. Conventional content analysis was used to analyze the findings.

Findings: The following themes emerged: (a) *overall clinical virtual simulation usability experience;* (b) *stepping into a nurse's shoes*; (c) *facilitating learning*; and (d) *clinical virtual simulation product and production.*

Conclusion: Nursing students and nurse faculty members had positive perceptions toward the usability of the clinical virtual simulation.

Keywords: nursing education; clinical simulation; virtual simulation; simulation education; usability

SUMMARY FOR LAY AUDIENCE

Simulation-based training is a principal method used in undergraduate nursing education to teach students important hands-on clinical skills, critical thinking, and clinical judgment. Recently, schools of nursing in some countries have begun using virtual technologies to enhance nursing students' clinical experiences and improve accessibility to simulation-based training. This technology remains a relatively new experience for both nursing students and nurse faculty members, and needs exploration pertaining to its usability from the perspective of people who play the simulation. Subsequently, the purpose of this research was to study how people played a virtual wound care simulation and whether it was easy to use (i.e., usability). Nursing students and nursing faculty were asked to talk-aloud whatever thoughts came to mind while trialing the virtual wound care simulation. Information from people talking about using the virtual wound care simulation was then examined and results were generated. These results included four different themes: (a) *overall clinical virtual simulation perceptions;* (b) *stepping into a nurse's shoes*; (c) *facilitating learning*; and (d) *clinical virtual simulation product and production.* Based on the findings of this study, more research is needed in this area to further develop virtual wound care simulation tools for undergraduate nursing education.

CO-AUTHORSHIP STATEMENT

Samantha Cooke was able to complete this thesis work under the supervision and guidance of Dr. Richard Booth and advisement of Dr. Siobhán O'Connor. Should publications result from this manuscript their names will appear as co-authors.

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CHAPTER ONE

This chapter provides a summary of the background information and relevant supporting literature pertaining to clinical virtual simulation and the importance of usability testing. Further, the rationale for conducting this study is summarized.

Background and Significance

Simulation-based training (SBT) is a common pedagogical approach used in undergraduate nursing education to assist in teaching clinical skills within controlled learning environments. Past research examining SBT has found that simulation activities can promote nursing students' development of hands-on clinical skills, improve knowledge acquisition (Cant & Cooper, 2017), and critical thinking abilities (Al Gharibi & Arulappan, 2020). Commonly, SBT replicates real experiences in which nursing students can safely explore various simulated clinical situations, problem solve, and even make mistakes without causing patient harm (Koukourikos et al., 2021). SBT activities typically occur in a simulation laboratory (i.e., commonly resembling a healthcare or hospital setting) (Koukourikos et al., 2021) where students are supervised by clinical instructors (Aebersold, 2018). Clinical instructors play a fundamental role in SBT by supporting students through challenging simulations and guiding their clinical decision-making (Soroush et al., 2021).

In its earliest days, SBT was facilitated using anatomical models, task trainers, and role-playing (Nehring & Lashley, 2009). More recently, standardized patient(s) (SP) and low- or high-fidelity manikins are commonly used in SBT activities (Lavoie & Clarke, 2017). According to the Healthcare Simulation Dictionary (Agency for Healthcare Research and Quality [AHRQ], 2020), a SP is defined as "an individual trained to portray a patient with a specific condition in a realistic, standardized, and repeatable way and where portrayal/presentation varies based only on learner performance" (AHRQ, 2020, p. 49). SPs also present realistic "body language, the physical findings, and emotional and personality characteristics" (AHRQ, 2020, p. 49). In nursing education, SPs have been used to evaluate students' communication, interviewing, and assessment skills (Nehring & Lashley, 2009). The use of SPs within nursing education has been shown to improve nursing students' satisfaction (Cabañero-Martínez et al., 2021), promote self-confidence, decrease anxiety (Labrague et al., 2019), and foster therapeutic communication skills (Donovan & Mullen, 2019). While effective as a pedagogical intervention, the financial costs commonly associated with the use of SPs has been perceived as a limitation by some researchers (Bosse et al., 2015; Demiray & Ilaslan, 2019). Bosse et al. (2015), conducted a study comparing the cost-effectiveness of peer role play to SPs in simulated undergraduate medical education. The results demonstrated relatively high-performance scores in both the intervention (81.6% ± 3.32%) and control (78.0% ± 6.23%) groups; however, the "absolute costs were 53.6% higher for training" using SPs than using peer role play (p. 4). Additionally, SPs are labor and time intensive as nurse educators need to liaise with them regularly to ensure proper teaching delivery (Demiray & Ilaslan, 2019). Along with the use of SPs, SBT in nursing education also commonly leverages the use of life-sized dolls called simulation manikins. A manikin's fidelity, the degree of reality portrayed by an object, is divided into two categories -- low and high (Nehring & Lashley, 2009). The first low-fidelity manikin was built in 1911 and was used to train nurses to mobilize and transfer patients (Aebersold, 2018). By the 1990s, development of high-fidelity manikins that possessed the ability to mimic human body functions, including respiratory, cardiac, and gastrointestinal sounds, began to be introduced (Aebersold, 2018; AHRQ, 2020). The use of simulation manikins in SBT allows students to observe various physiological functions that SPs are not able to produce. For instance, simulation manikins produce palpable pulses, audible cardiac and respiratory sounds, and eye and pupil movements, all of which can be manipulated to simulate various clinical situations (Meerdink & Khan, 2021). For example, wheezing and tachycardia can be simulated to teach nursing students how to care for a patient experiencing an asthma attack. However, like SPs, simulation manikins are expensive to procure, and some nursing students have described communicating and interacting with a plastic doll as difficult and unnatural (Handeland et al., 2021).

SPs and simulation manikins are two common methods used to facilitate SBT in nursing education. Due to both external and internal pressures such as lack of clinical placement settings, decreases in nurse faculty members, and implications brought on by the SARS-CoV-2 (COVID-19) pandemic, education institutions are increasingly relying on the use of simulation to facilitate clinical learning for nursing education (Kim et al., 2021; Koukourikos et al., 2021; Saab et al., 2021). In response to these challenges, nurse educators are tasked with continuing to develop high-quality clinical simulations to prepare nursing students for entry into practice while struggling with a lack of educational resources (Saab et al., 2021). One such solution includes the integration of virtual teaching methods (Kim et al., 2021), including *virtual simulation*. A virtual simulation is defined as the “re-creation of reality depicted on a computer screen” and “involves real people operating simulated systems” (AHRQ, 2020, p. 56). The transition to virtual simulations in Canadian nursing education has been accelerated by the COVID-19 pandemic as a method to provide nursing students with access to clinical learning opportunities during lockdown periods when universities and hospitals were restricted from conducting clinical teaching (Canadian Association of Schools of Nursing [CASN], 2021). According to a recent national survey conducted by the CASN (2021), 74 percent (n = 138, 74%) of respondents (N = 186) reported that virtual simulations had been “introduced into areas where they had not previously been used" (p. 7) during the pandemic and 31 percent (n = 58, 31%) of respondents (N = 186) reported using virtual simulations for the first time during the pandemic. Although the COVID-19 pandemic was a catalyst in the rapid adoption of virtual simulations in nursing education, nurse researchers anticipate its use will continue to grow for years to come (Luctkar-Flude & Tyerman, 2021). However, prior to widespread adoption into nursing curriculum, it is imperative that nursing students' and nurse faculty members' usability experiences are explored to ensure that virtual simulations meet the needs of end-users. For the purpose of this research, the concept of *usability* was defined as the "capacity of [a] system to allow users to carry out their tasks safely, effectively, efficiently, and enjoyably" (Ali et al., 2018, p. 175; Preece et al., 2002). The exploration of system usability typically involves the participation of end-users in the trial, testing, and evaluation of a product or system to determine what aspects are satisfactory and if further improvements are warranted prior to general use (Moran, 2019). While usability exploration is a common activity performed in technology and product evaluation domains, "it is often neglected by [nurse] educators, and the consequences are dissatisfied users and under-used products" (Verkuyl et al., 2018, p. 83). Given the current novelty and probable increased adoption of virtual simulation in nursing education over the coming decade, further inquiry exploring the usability of this kind of educational technology from the perspective of end-users is urgently required (Zhang et al., 2020).

Wound Care Focus

Wound care is a foundational nursing skill that requires knowledge related to the pathophysiology of prevention, treatment, and healing of tissue (Abuleal, 2018), and is a core clinical competency within nursing education (Bobbink et al., 2022). To successfully perform wound care, nursing students must develop both wound dressing skills and knowledge related to the principles of wound assessment, management, sterility, and recovery (Abuleal, 2018). Previous research has highlighted that factors such as time constraints and inconsistencies in education delivery methods have negatively impacted nursing students' and faculty members' perceptions of wound care education (Kielo-Viljamaa et al., 2022; Welsh, 2018). Based on these challenges, some nurse researchers have begun researching how virtual simulations may help to bridge the current gap in wound care education (Choi, 2022). Recently, Choi (2022) conducted a study investigating nursing students' acceptance and usability of a wound dressing virtual simulation. Results from this study demonstrated that the virtual simulation was well accepted by nursing students and that the system's usability was satisfactory. However, Choi (2022) concluded that "additional research is needed to confirm the usability of the system" once further revisions related to the realism and comprehensiveness of the virtual simulation have been improved (p. 56). Based on the current gaps in knowledge related to the use of virtual simulation to aid in teaching wound care, further investigation is required.

Statement of Study Purpose

The purpose of this study is to explore the usability experiences of nursing students and nurse faculty members who trialed an in-house designed and developed clinical virtual simulation (CVS) used to demonstrate a wound dressing change (WDC). The findings of this study will assist in the future prototype development of the WDC CVS and will expand upon the growing body of literature related to virtual simulations used in undergraduate nursing education.

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CHAPTER TWO

This chapter provides a detailed description of the background information and supporting literature required to understand the context and rationale for pursuing this research study. The theoretical lens, study design, and research methods used in this study are also discussed in depth. Finally, the research findings from the data analysis are provided and discussed within the context of this study.

Background

Over the last decade and more recently accelerated by the COVID-19 pandemic, nurse educators have increasingly incorporated innovative technologies such as *virtual simulation* into simulation-based training (SBT) (Saab et al., 2021; Verkuyl et al., 2021). The Healthcare Simulation Dictionary defines virtual simulation as the “re-creation of reality depicted on a computer screen” and “involves real people operating simulated systems” (Agency for Healthcare Research and Quality [AHRQ], 2020, p. 56). Virtual simulation provides an interactive learning experience that is consistent, repeatable, and flexible (Chen et al., 2020). Despite some nursing programs having integrated virtual simulation into curricula, this type of technology remains a relatively new experience for both nursing students (Saab et al., 2021) and nurse faculty members (Van Der Wedge et al., 2021).

Of the current research that exists examining virtual simulation in nursing education, exploration has commonly focused on assessment aspects of: (a) commercially developed virtual simulations; or, (b) in-house developed virtual simulations. While commercially available virtual simulations (e.g., Body Interact, vSim, Second Life, and iHuman) are fully developed platforms that can be readily deployed in education, the substantive licensing costs commonly required to procure and sustain subscription to these kinds of virtual simulations can present as a barrier to adoption (Killam et al., 2021; Lange et al., 2020). Further, it has been reported that commercial products are typically unlikely to meet all course objectives or address specific learning needs identified by faculty members (Killam et al., 2021; Van Der Wedge et al., 2021). This may prompt nurse educators to attempt to build or develop *in-house* solutions, where the costs and functionality of the virtual simulation can be better controlled by the educator (Killam et al., 2021). For example, Tyerman et al. (2021) described the development of a COVID-19 personal protective equipment virtual simulation, since at the time of the simulation's development a commercially available pandemic preparation simulation did not exist.

Along with published descriptions of virtual simulation, other research inquiry has occurred over the last few years exploring the use of this kind of educational intervention. For instance, a systematic review completed by Shorey and Ng (2021) exploring the use of virtual simulations among registered nurses and students concluded that virtual learning yielded higher time-cost-effectiveness education outcomes compared to manikin-based simulation. However, in the same study, technological issues and lack of realism were identified as barriers to the use of virtual simulation (Shorey & Ng, 2021). A mixed-methods study by Jimenez-Rodriguez et al. (2020) exploring nursing students' perceptions of a simulated video consultation found that 97.8 percent (n = 91, 97.8%) of participants (N = 93) expressed high overall satisfaction with the simulation. Mixed findings emerged in a qualitative analysis conducted by Kim et al. (2021) exploring nursing students' experiences using a commercial virtual simulation called vSim. Participants stated that there were benefits to the virtual simulation; however, gaps in satisfaction related to lack of reality and limited functioning emerged as a theme (Kim et al., 2021). From an educator perspective, Breitkreuz et al. (2021b), conducted a mixed-methods study exploring faculty members' usability experiences of a virtual catheter simulation. Breitkreuz et al. (2021b) found that overall nurse faculty members enjoyed the virtual simulation; however, quantitative data demonstrated that participants (*N* = 37) scored the system's usability as 47 out of a possible 100 points, indicating a "low-medium" (p. 53) score. Further, Breitkreuz et al. (2021b) concluded that there is currently a knowledge gap related to understanding the usability experience of participants using virtual simulation for education purposes. Subsequently, due to the novelty of virtual simulation in nursing education and the infancy of the current knowledge base, further research exploring end-users' usability experiences related this technology is warranted.

For the purpose of this research, the concept of *usability* was defined as the "capacity of the system to allow users to carry out their tasks safely, effectively, efficiently, and enjoyably" (Ali et al., 2018, p. 175; Preece et al., 2002). Usability exploration involves representative end-users trialing a product to determine what aspects are satisfactory and if further improvements are warranted prior to general use (Moran, 2019). Although usability exploration is commonly performed and understood in the information technology domain, "it is often neglected by [nurse] educators, and the consequences are dissatisfied users and under-used products" (Verkuyl et al., 2018, p. 83). The novelty of virtual simulation warrants further extensive inquiry to explore the usability of such technology as perceived by end-users (i.e., nursing students and nursing faculty members). In doing so, insight pertaining to the usability and areas of improvement can be generated to inform the successful and sustainable development of virtual simulation for undergraduate nursing curricula.

Wound Care Focus

One complex clinical skill taught to undergraduate nursing students using SBT is wound care. Wound care is a foundational nursing skill that requires knowledge related to the pathophysiology of prevention, treatment, and healing (Abuleal, 2018). To successfully perform wound care, nursing students must develop comprehensive wound dressing change skills and knowledge related to wound assessment, management, sterility, and recovery (Abuleal, 2018). Wound care training is typically conducted through lecture, third-person video demonstration, and practice on a manikin with a simulated wound (Choi, 2022). Previous research has highlighted that factors such as time constraints and inconsistencies in education delivery methods have negatively impacted nursing students' and faculty members' perceptions of wound care education (Abuleal, 2018; Kielo-Viljamaa et al., 2022; Welsh, 2017). For example, Abuleal (2018), conducted a quantitative study examining nursing students' and faculty members' perceptions toward wound care education. Survey data demonstrated 73 percent (n = 92, 73%) of second-year undergraduate nursing students (N = 126) were not satisfied with the time allotted to practice wound care and 43 percent (n = 54, 43%) were not satisfied with the wound care education they received (Abuleal, 2018). Further, 46 percent (n = 20, 46%) of nurse faculty members (N = 44) stated that they were not satisfied with the wound care education delivered to students; and, 69 percent (n = 30, 69%) were not satisfied with the wound care education resources used to facilitate learning (Abuleal, 2018). Deficits in undergraduate wound care education have translated into challenges in wound management for nurses in practice (Welsh, 2018). For example, in a semi-systematic review, Welsh (2018) found that nurses had insufficient knowledge related to wound care and that more structured education on this topic is required in nursing curricula. Consequently, nurse researchers have begun exploring how virtual simulation may help to bridge the current gap in wound care education (Choi, 2022). Redmond et al. (2020), conducted a cross-sectional study to evaluate the use of a virtual patient to increase nursing students' competence in wound care. Results from the study demonstrated that students felt the virtual patient presented a safe learning environment and an opportunity to improve their competency (Redmond et al., 2020). More recently, Choi (2022) conducted a study investigating nursing students' acceptance and usability of a virtual simulation wound dressing system. Results from this study demonstrated that the virtual simulation was well accepted by nursing students and that the usability of the system was satisfactory (Choi, 2022). However, "additional research is needed to confirm the usability of the system" related to the author's plans to improve the realism and comprehensiveness of the virtual simulation (Choi, 2022, p. 56).

Purpose

Based on the current challenges presented, it is evident that more structured and consistent wound care education is required in undergraduate nursing curricula (Welsh, 2018). To help address this gap, researchers in the present study designed and developed an in-house wound dressing change (WDC) clinical virtual simulation (CVS), as a platform to explore nursing students' and faculty members' usability experiences. Further, description of the design and development of the in-house WDC CVS is provided in the corresponding sections below.

Theoretical Framework

In Ericsson and Simon's (1980) work, titled "Verbal Reports as Data", the *Think Aloud* method is situated within the theoretical framework of Human Information Processing. According to Simon and Newell (1971), the *Human Information Processing Theory* views humans as processors of information. The information processes exist in the central nervous system, internal to the individual human where information is filtered, stored, and retrieved (Simon & Newell, 1971). The Human Information Processing Theory is composed of the following concepts: (a) *recognition*; (b) *long-term memory* (LTM); (c) *short-term memory (STM)*; (d) *control of attention*; (e) *verbalization process*; and (f) *retrospective reports* (Ericsson

& Simon, 1980). The concept of *recognition* posits that information received from sensory organs resides for a short period of time in memories (Ericsson & Simon, 1980). Portions of the memories are recognized and encoded using information previously stored in LTM (Ericsson & Simon, 1980). *LTM* is described as enormous collections of interrelated information, referred to as nodes (Ericsson & Simon, 1980). Nodes can be accessed through recognition or association; however, association processes are much slower than recognition processes (Ericsson & Simon, 1980). The central processor, which regulates nonautomatic cognitive processes, determines what information is stored in *STM* (Ericsson & Simon, 1980). The amount of information that can be stored in STM is much smaller than the amount that can be stored in LTM (Ericsson & Simon, 1980). As new information comes into STM, previously stored information may be lost (Ericsson & Simon, 1980). Other concepts in action during this larger process include *control of attention,* referring to information that may be lost from STM if a human is interrupted while performing a task; and, the *verbalization process,* whereby verbalized information is actively processed and stored in STM (Ericsson & Simon, 1980). The verbal-information encoding process that occurs when an individual describes their ideas or actions aloud (i.e., *verbalization process)* helps to evoke dedicated mental references to the information stored in the STM (Ericsson & Simon, 1980). During the final concept of the theory, *retrospective reports*, participants are asked to report on what they remember following the completion of a cognitive process or task (Ericsson & Simon, 1980). If retrospective questioning is performed immediately after performing a task, the *Human Information Processing Theory* posits that direct memory reporting can be achieved through STM and some LTM may also be elicited through association (Ericsson & Simon, 1980).

The *Human Information Processing Theory* was used to conceptualize the *Think Aloud* (TA) data collection method, drawing on aspects from individuals' STM and verbalization processes (Ericsson & Simon, 1980). TA methods involve a participant interacting with a system or product while verbalizing their thoughts aloud for others to hear (Ericsson & Simon, 1980). Through TA methods, researchers capture verbal data in real-time (Ericsson & Simon, 1980) that would otherwise be difficult to obtain from mere observation (Fan et al., 2020) or lost from the STM when new information is received (Ericsson & Simon, 1980).

Think Aloud: Theory to Practice

When implementing the TA method, researchers must adhere to four guiding principles. In the first guiding principle, researchers must collect and analyze reliable data, referred to by Ericsson and Simon (1980) as *verbalizations*. Ericsson and Simon (1980) describe three levels of verbalizations, two of which (i.e., level one and level two) are considered reliable. *Level one* verbalizations are those that are not transformed before initiation of speech (Boren & Ramey, 2000). For example, a participant verbalizes numbers while solving a mathematical equation (Boren & Ramey, 2000). *Level two* verbalizations are those that require transformation prior to speech initiation (Boren & Ramey, 2000). For example, a participant describes images or abstract concepts (Boren & Ramey, 2000). Finally, *level three* verbalizations are those that require cognitive processes, including scanning and filtering of contextual information prior to speech initiation (Ericsson & Simon, 1980). For example, asking a participant to only verbalize information related to a specific topic (Ericsson & Simon, 1980).

The second guiding principle of the TA method encourages researchers to provide participants with detailed initial instructions pertaining to their role (Boren & Ramey, 2000). For example, explaining the procedure clearly and encouraging the participant to speak constantly throughout task performance (Boren & Ramey, 2000). The third guiding principle of the TA method suggests that during task performance, researchers should remind participants to *think aloud* during periods of prolonged silence (Ericsson & Simon, 1993). Ericsson and Simon recommend using the simple and nondirective phrase "keep talking" as a prompt (Ericsson & Simon, 1993, p. 83). The final guiding principle describes that after the task commences, researchers should avoid interaction with participants to prevent interfering with their thought processes (i.e., control of attention) (Ericsson & Simon, 1993). As described in the third principle, researchers are only permitted to communicate with participants when reminding them to continue thinking aloud during the occurrence of prolonged silence (Boren & Ramey, 2000).

The TA method is commonly implemented in usability testing to elicit insights pertaining to participants' thought processes and has been described in the literature as "the single most valuable" practice to conduct usability exploration (Boren & Ramey, 2000, p. 261). Recently, nurse researchers have begun trialing TA methods to explore participants' experiences related to the usability of various virtual simulation modalities (Butt et al., 2018; Luctkar-Flude et al., 2021a; Luctkar-Flude et al., 2021b; Verkuyl et al., 2018). Thus, the TA method was selected to inform data collection in the present study.

Literature Review

A literature review was completed to ensure an appropriate understanding of the concepts presented in this study, including aspects surrounding the usability of CVS for nursing education. In this literature review, the concept of *usability* was defined as the "capacity of the system to allow users to carry out their tasks safely, effectively, efficiently, and enjoyably" (Ali et al., 2018, p. 175; Preece et al., 2002). A search of the literature was conducted in the following electronic databases: Cumulative Index to Nursing and Allied Health Literature, Scopus, PubMed, and Google Scholar. The following keywords were used as search terms in various combinations: *clinical virtual simulation; virtual simulation; nursing student; undergraduate nursing; nurse faculty; nurse educator; nurse instructor; usability, evaluation, perceptions; outcomes;* and *assessment*. Boolean operators such as "AND/OR" and truncation symbols such as asterisk "*" were also used in conjunction with search terms (Polit & Beck, 2021). For this review, virtual simulation was defined as "a type of clinical experience where interactions with patients are performed virtually on a computer or other digital learning environment, in ways that parallel real-world engagement" (Laerdal Medical, n.d., para. 1). Therefore, articles studying both virtual simulations delivered through head-mounted displays and computer-based applications were included for review. English language, peer-reviewed, primary research articles published in the past five years (2018-2022) were included in this review. Unpublished manuscripts such as abstracts, theses, and dissertations were excluded. Editorials, scoping reviews, and conference papers were also excluded. Articles were uploaded to Covidence systematic review software (Veritas Health Innovation, Australia) (2022) for title and abstract screening and full text review. A total of 14 articles were included for review. The following three themes were summarized and described narratively (Arksey & O'Malley 2005; Levac et al., 2010): (a) *virtual simulation usability evaluation* (subthemes: quantitative evaluation and qualitative evaluation); (b) *virtual simulation usability challenges* (subthemes: accessibility, and cybersickness); (c) and *areas of virtual simulation improvement* (subthemes: guidance for new learners and technology issues).

Summary of Articles

A total of 14 articles were selected for final review, including five studies published in the United States (Butt et al., 2018; Breitkreuz et al., 2021a; Breitkreuz et al., 2021b; Kardong-

Edgren et al., 2019; Samosorn et al., 2020), three studies published in Canada (Luctkar-Flude et al., 2021a; Luctkar-Flude et al., 2021b; Verkuyl et al., 2018), two studies published in Korea (Kim et al., 2021; Lee et al., 2020), one in Portugal (Padhila et al., 2018), one in Japan (Shibuya et al., 2019), one in Ireland (Saab et al., 2021), and one in the United Kingdom (Adhikari et al., 2021). Research designs included nine mixed-methods studies (Adhikari et al., 2021; Butt et al., 2018; Breitkreuz et al., 2021a; Breitkreuz et al., 2021b; Kim et al., 2021; Lee et al., 2020; Luctkar-Flude et al., 2021a; Luctkar-Flude et al., 2021b; Verkuyl et al., 2018), four quantitative studies (Kardong-Edgren et al., 2019; Padilha et al., 2018; Samosorn et al., 2020; Shibuya et al., 2019), and one qualitative study (Saab et al., 2021). Ten articles studied nursing students (Adhikari et al., 2021; Breitkreuz et al., 2021a; Butt et al., 2018; Kim et al., 2021; Lee et al., 2020; Luctkar-Flude et al., 2021a; Padilha et al., 2018; Saab et al., 2021; Shibuya et al., 2019; Verkuyl et al., 2018) three studied both nursing students and nurse faculty members (Kardong-Edgren et al., 2019; Luctkar-Flude et al., 2021; Samosorn et al., 2020) and one article studied nurse faculty solely (Breitkreuz et al., 2021b). Head-mounted display modalities were identified as the most common technology studied (n = 10) (Adhikari et al., 2021; Breitkreuz et al., 2021a; Breitkreuz et al., 2021b; Butt et al., 2018; Kardong-Edgren et al., 2019; Kim et al., 2021; Lee et al., 2020; Saab et al., 2021; Samosorn et al., 2020; Shibuya et al., 2019) followed by computer-based VR applications (n = 4) (Padilha et al., 2018; Luctkar-Flude et al., 2021a; Luctkar-Flude et al., 2021; Verkuyl et al., 2018). The most common nursing skill taught was urinary catheterization (n = 4) (Butt et al., 2018; Breitkreuz et al., 2021a; Breitkreuz et al., 2021b; Kardong-Edgren et al., 2019), followed by mental health (n = 2) (Lee et al., 2020; Verkuyl et al., 2018) and airway management/respiratory distress (n = 2) (Luctkar-Flude et al., 2021a; Samosorn et al., 2020). Other clinical topics covered included the following: blood transfusion and intradermal injection (n = 1) (Kim et al., 2021), sepsis (n = 1) (Adhikari et al., 2021), tracheostomy suctioning (n = 1) (Shibuya et al., 2019), sexual orientation and gender identity (n = 1) (Luctkar-Flude et al., 2021b), and testicular disease (n = 1) (Saab et al., 2021). Finally, one (n = 1) article did not identify what nursing skill was taught (Padilha et al., 2018).

A variety of data collection methods were used throughout the articles; however, a mixed methods approach, including post-hoc surveys and semi-structured interviews, was most common (Adhikari et al., 2021; Breitkreuz et al., 2021a; Breitkreuz et al., 2021b; Kim et al., 2021; Lee et al., 2020). Four of the nine mixed methods studies used a *think aloud* approach followed by semi-structured interviews with participants (Butt et al., 2018; Luctkar-Flude et al., 2021a; Luctkar-Flude et al., 2021b; Verkuyl et al., 2018). Likert scale surveys were used in all articles that reported quantitative findings (Adhikari et al., 2021; Breitkreuz et al., 2021a; Breitkreuz et al., 2021b; Butt et al., 2018; Kardong-Edgren et al., 2019; Kim et al., 2021; Lee et al., 2020; Luctkar-Flude et al., 2021a; Luctkar-Flude et al., 2021b; Padilha et al., 2018; Samosorn et al., 2020; Shibuya et al., 2019; Verkuyl et al., 2018). Some articles used measurement instruments that had previously been standardized and validated. For example, the *System Usability Scale* (SUS) (Brooke, 1996) (α = 0.92, r = 0.822), a ten-item Likert scale, was used to measure nursing students' perceived effectiveness, efficiency, and satisfaction toward a catheterization virtual simulation (Breitkreuz et al., 2021a). In a mixed-methods study exploring the usability of a virtual simulation to teach nursing students urinary catheterization, Butt et al. (2018) developed the *User Reaction Survey* (URS) (no validity or reliability data reported), a 24-item Likert scale, used to measure engagement, satisfaction, overall confidence, and perceived impact on learning. The URS was utilized as a measurement tool in three other articles selected for this review (Breitkreuz et al., 2021a; Breitkreuz et al., 2021b; Kardong-Edgren et al., 2019).

Two studies utilized the *Virtual Simulation Game Technology Acceptance Survey* (VSG-TAS) (Bertrand & Bouchard, 2008) (α = 0.80), a five-item Likert scale, used to measure the ease of use and usefulness of a virtual simulation (Luctkar-Flude et al., 2021a; Luctkar-Flude et al., 2021b). Finally, some articles analyzed did not specify the survey utilized to collect quantitative data pertaining to the usability of the virtual simulation (Lee et al., 2020; Padilha et al., 2018).

Virtual Simulation Usability Evaluation

Quantitative Evaluation

Various aspects of usability were reported across the articles selected for review. For example, multiple articles focused on evaluating the efficiency of the virtual simulation by assessing its ease of use and usefulness (Butt et al., 2018; Breitkreuz et al., 2021b; Breitkreuz et al., 2021b; Kardong-Edgren et al., 2019; Kim et al., 2021; Lee et al., 2020; Luctkar-Flude et al., 2021a; Luctkar-Flude et al., 2021b; Padilha et al., 2018; Verkuyl et al., 2018). In a mixed methods study examining a virtual simulation game designed to teach urinary catheterization, the SUS and URS were used to collect usability data from nursing students (Breitkreuz et al., 2021a). From this data, researchers were able to conclude that the virtual simulation yielded a medium level of usability and that 85 percent (n = 255, 85%) of students (N = 300) agreed or strongly agreed that the virtual learning environment was enjoyable (Breitkreuz et al., 2021a). In other articles, researchers explored usability by assessing the effectiveness of various virtual simulations by examining learning-specific outcomes such as skill competency (Kim et al., 2021), skill assessment (Shibuya et al., 2019), and knowledge (Samosorn et al., 2020). For example, Shibuya et al. (2019) used a pretest-posttest design to assess the influence of a virtual simulation teaching material on nursing students' skill assessment scores related to tracheostomy suctioning. Participants were randomly assigned into the following three groups: (a) virtual simulation intervention (first-person video); (b) traditional intervention (third-person video); and (c) no intervention (Shibuya et al., 2019). Statistical analysis demonstrated that the skills assessment scores of the virtual simulation and traditional intervention groups were significantly greater than the no intervention group (Shibuya et al., 2019). However, the difference between the virtual simulation and traditional intervention groups was not statistically significant (Shibuya et al., 2019). Kim et al. (2021) also explored the effectiveness of a virtual simulation by examining nursing students' skill competency pertaining to intradermal injection and blood transfusion using a pretest-posttest design. A paired two-tailed *t*-test was used to analyze differences between pre-and post-intervention nursing skill competency scores (Kim et al., 2021). Nursing skill competency was assessed using a ten-point Likert scale (no validity or reliability data reported). A statistically significant improvement was achieved in both skills after the virtual simulation (p = <.001) as mean scores increased from 7.23 (SD = 1.17) to 8.90 (SD = 0.85) (intradermal injection) and 6.17 (SD = 1.64) to 8.50 (SD = 0.97)" (blood transfusion) (Kim et al., 2021, p. 7). Lastly, in the mixed-methods study by Samosorn et al. (2020), researchers assessed participants' knowledge pertaining to airway insertion using a pretest-posttest design. Knowledge was assessed using a researcher-developed scale that was reviewed by experts in airway management and "judged to have content validity" (Samosorn et al., 2020, p. 21). Researchers found nurse faculty mean post-test scores (M = 13, SD = 1.8) were significantly higher than mean pre-test scores (M = 9, SD = 3.0), with the "effect size… 1.76 or between very large and huge" (Samosorn et al., 2020, p. 39). Further, nursing students' mean post-test scores (M = 12, SD = 2.7) were also significantly higher than mean pre-test scores (M = 6, SD = 2.7) with the "effect size… determined to be 2.33 or huge" (Samosorn et al., 2020, p. 39). Finally, Adhikari et al. (2021), assessed the usability of the virtual simulation sepsis game by exploring nursing students' (*n* = 19) pre- and post- intervention self-efficacy and anxiety scores. Participants completed the *Nursing Anxiety and Self-Confidence with Clinical Decision-Making Scale,* (White, 2014), to assess perceived self-confidence (α = 0.97) and anxiety (α = 0.96) (Adhikari et al., 2021). This scale possessed 27 items and used a six-point Likert scale with two sub-scales: anxiety (α = 0.96) and self-confidence (α = 0.97) (Adhikari et al., 2021). Statistical analysis demonstrated a 26.1% increase in mean confidence scores and a 23.4% decrease in mean anxiety scores (Adhikari et al., 2021).

Qualitative Evaluation

In addition to using quantitative metrics, several articles used qualitative (some via a mixed-methods methodology) approaches to explore the usability of various virtual simulation modalities (Adhikari et al., 2021; Breitkreuz et al., 2021a; Breitkreuz et al., 2021b; Kim et al., 2021; Lee et al., 2020; Luctkar-Flude et al., 2021a; Luctkar-Flude et al., 2021b; Saab et al., 2021; Samosorn et al., 2020; Verkuyl et al., 2018). Overall, participants spoke positively about the various virtual simulation modalities explored in each study. For example, in the Breitkreuz et al. (2021b) study, a nurse faculty member stated, "I felt this was an excellent tool to learn and improve nursing skills" (p. 55). Verkuyl et al. (2018), conducted a mixed method study exploring nursing students' experiences toward the usability of a mental health virtual simulation game. Overall, all students shared positive perceptions (Verkuyl et al., 2018). For instance, "[i]t brings to life an experience you might not have in your own experiences or clinical" (Verkuyl et al., 2018 p. 86).

Further, in multiple studies, participants spoke to the efficiency of various virtual simulation modalities (Adhikari et al., 2021; Kim et al., 2021; Luctkar-Flude et al., 2021a;

Luctkar-Flude et al., 2021b). For instance, one student participant in the Kim et al. (2021) study stated that the Smart Glasses were "quite straightforward, I figured out how it works right away" (p. 8). Similarly, a participant in the Luctkar-Flude et al. (2021a) study commented that the virtual simulation game was "very easy, simple, and straightforward" (p. 39).

Virtual Simulation Usability Challenges

Accessibility

Throughout the articles explored, *accessibility* was identified as a sub-theme related to the usability of various virtual simulations. Multiple participants who wore glasses reported discomfort when required to wear the head-mounted display during the virtual simulation (Breitkreuz et al., 2021a: Kardong-Edgren et al., 2019; Kim et al., 2021; Lee et al., 2020). A participant in the Lee et al. (2020) study exploring the usability of a mental health virtual simulation stated, "[t]he device seems not to be meant for people wearing glasses. It was painful" (p. 8). According to Kardong-Edgren et al. (2019), minor modifications can be made in the headgear to compensate for prescription glasses. However, for some users the modifications were insufficient to compensate for participants' eyesight prescription requirements; therefore, limiting the usefulness and accessibility of the virtual simulation (Kardong-Edgren et al., 2019). Additionally, two studies reported challenges pertaining to right versus left-hand dominance (Breitkreuz et al., 2021b; Kardong-Edgren et al., 2019). In a quantitative study evaluating the usability of a catheterization virtual simulation among nursing students and faculty members (*N* = 31), Kardong-Edgren et al. (2019) found that left-handed players reported more difficulties playing the game compared to right-handed players, thus creating barriers in accessibility.

Cybersickness

Finally, four articles reported that some participants experienced dizziness, vertigo, or nausea during the virtual simulation (Lee et al., 2020; Saab et al., 2021; Shibuya et al., 2019; Verkuyl et al., 2018). For example, in a quantitative study exploring nursing students' experiences using head-mounted display to teach tracheostomy suctioning, Shibuya et al. (2019) found that 12 participants (N = 36) experienced mild cybersickness (i.e., nausea). Further, Lee et al. (2020) reported that five percent (n = 3, 5%) of participants (N = 60) described experiencing dizziness after the head-mounted display virtual simulation. The presence of cybersickness was not reported in virtual simulations that utilized computer-based applications. Some articles highlighted that the experience of cybersickness during virtual simulation was uncommon or not reported by participants (Breitkreuz et al., 2020a; Breitkreuz et al., 2020b; Kardong-Edgren et al., 2019; Samosorn et al., 2020). For example, in a quantitative study exploring the usability of a head-mounted display to teach airway insertion to nursing students and faculty, Samosorn et al. (2020) used the *Virtual Reality Sickness Questionnaire* (Kim et al., 2018) (α = 0.847) to assess the presence cybersickness. Based on the results from the questionnaire, researchers reported that participants experienced little to no cybersickness (Samosorn et al., 2020).

Areas of Virtual Simulation Improvement

Guidance for New Learners

In the studies conducted by Breitkreuz et al. (2020b); Lee et al. (2020); Luctkar-Flude et al. (2021a); and Verkuyl et al. (2018), areas of improvement related to guidance and familiarity for new learners emerged in the literature. Some participants in both the Breitkreuz et al. (2020b) and Lee et al. (2020) studies noted that they were unfamiliar with how to operate within the virtual simulation environment or use the equipment. For example, in the study conducted by Lee et al. (2020), roughly one third *(n* = 14) of nursing students (*N* = 40) reported difficulty operating the virtual simulation device; however, they were able to "get used to it right away" (p. 9). In the Verkuyl et al. (2018) study, although the mean score for the survey item "[i]t was easy to learn to use the community home visit simulation" was 4.5 (*SD* = 0.67) out of five, participants (*N* = 12) noted that more detailed instructions at the beginning of the virtual simulation would be helpful. Finally, in the mixed methods study exploring the usability of a respiratory distress virtual simulation, Luctkar-Flude et al. (2021a) highlighted that one participant suggested incorporating a trial round to allow participants to familiarise themselves with the virtual environment (Luctkar-Flude et al., 2021a).

Technology Issues

Of the 14 articles included, eight studies reported technological issues with the virtual simulation methods studied (Adhikari et al., 2021; Breitkreuz et al., 2021a; Breitkreuz et al., 2021b; Butt et al., 2018; Kim et al., 2021; Lee et al., 2020; Luctkar-Flude et al., 2021b; Verkuyl et al., 2018). The most common issues described were problems with the software, including technical glitches, software bugs, and interface freezing (Adhikari et al., 2021; Breitkreuz et al., 2021a; Breitkreuz et al., 2021b; Butt et al., 2018; Kim et al., 2021; Lee et al., 2020; Luctkar-Flude et al., 2021b; Verkuyl et al., 2018). For example, in a mixed-methods study exploring nurse faculty members' perceptions of a catheterization virtual simulation, one participant stated, "[t]here was a slight lag and glitch that impeded fluid muscle movement. It became frustrating when the finger and thumb would not respond in the game and took my focus off of maintaining a sterile field" (Breitkreuz et al., 2021b, p. 55). Further, in the mixed-methods study conducted by Verkuyl et al. (2018), exploring nursing students' and faculty members' perceptions of a mental health virtual simulation, researchers reported technical issues, "such as the need to frequently refresh the browser" (p. 86). Participants stated that it was important to improve the glitches to promote increased usability of the virtual simulation and decrease participant frustration (Breitkreuz et al., 2021a; Breitkreuz et al., 2021b).

Research Question

What are the usability experiences of nursing students and faculty who trialed an in-house designed and developed clinical virtual simulation used to demonstrate a wound dressing change?

Methods

Study Design

This study was conducted using a qualitative descriptive design, informed by elements of Graneheim and Lundman's (2004) and Hsieh and Shannon's (2005) approaches to conventional content analysis. Researchers developed a prototype, first-person, WDC CVS to elicit data related to nursing students' and nurse faculty members' usability experiences. For the purpose of this study, usability was defined as the "capacity of the system to allow users to carry out their tasks safely, effectively, efficiently, and enjoyably" (Ali et al., 2018, p. 175; Preece et al., 2002). Exploring usability involves representative end-users trialing a product to determine what aspects are satisfactory and if further improvements are warranted prior to general use (Moran, 2019). Although usability testing is commonly performed and understood in the information technology domain, "it is often neglected by [nurse] educators, and the consequences are dissatisfied users and under-used products" (Verkuyl et al., 2018, p. 83). Therefore, exploring the usability of the WDC CVS as perceived by end-users' (i.e., nursing students and nurse faculty members) is essential. The TA method, in which participants are asked to speak aloud their thoughts while interacting with a product, was used to collect real-time data pertaining to usability experiences. Data was also collected through individual interviews. Conventional content analysis was performed to analyze the data, whereby content categories were derived using interpretive methods informed by Graneheim and Lundman (2004) and Hsieh and Shannon (2005). This study was approved by the Health Sciences Research Ethics Board (REB 119989) and the Arthur Labatt Family School of Nursing at Western University, London, Ontario (Appendix A). The following sections describe the WDC CVS development, sample, setting, data collection, and analysis.

Clinical Virtual Simulation Creation

Commonly, when nursing students first learn WDCs, a pre-recorded video of the procedure is used to assist students in learning the necessary steps and skills required to perform the task. These types of preparatory videos are typically recorded from a third-person perspective (Shibuya et al., 2019) and have a voiceover narration describing the steps performed by the nurse. To explore usability experiences of nursing students and nurse faculty members; a custom prototype level WDC CVS was generated by the researchers. The creation of an in-house simulation allowed the researchers to mimic the typical manner in which WDC procedures are taught to nursing students while incorporating a first-person perspective and interactive capabilities. To do this, several development steps were required and are briefly described in the following sections.

WDC CVS Workflow Design and Recording

To generate the WDC CVS, the development of a detailed gameplay workflow document was required to provide structural insights to the various steps and processes related to the WDC task. Subsequently, an extensive WDC CVS workflow document was created using the following steps: (a) current WDC techniques taught to Bachelor of Science in Nursing (BScN) students and best practice documents related to wound care were extensively reviewed (Arthur Labatt Family School of Nursing, 2019); (b) a visual workflow diagram describing each step of the WDC task was created; (c) the workflow WDC diagram was sent to nurses with expertise in wound care for external review; and, (d) feedback obtained from external review was incorporated into the finalized WDC workflow document that was used to assist with generation of the CVS (Appendix B). Contemporaneously, with development of the workflow, a more detailed step-by-step blueprint was generated to assist in recording various segments of the WDC CVS. For example, dialogue content and other clinical decision points that would be infused into the completed WDC CVS (Appendix C). Using this WDC CVS blueprint, nine video segments were recorded in first-person using a 360-degree camera (i.e., GoPro Max). After trialing various camera angles, researchers implemented the following best practices to facilitate recording fidelity:

1. Mounting of the GoPro camera to the chest of the researcher recording the video segments to ensure smooth recording as head-mounted recording resulted in jerky and potentially nausea-inducing video recording movements.
2. Positioning of the GoPro camera to a 45-degree angle to the main object being recorded to enable spatial presence.

3. Standing approximately two feet from the object being recording (i.e., bedside table) to maximize the fidelity and clarity of the recording, especially when viewing the video in 360-degree playback resolution.

Further, during the recording of the various video segments, the GoPro camera's front lens cap was removed; however, the back lens cap was kept on. Keeping the back lens cap on prevented the camera from capturing the recorder's face and body. Once the video recording was complete, videos were uploaded to GoPro Player, a desktop video editing application for processing. Processed videos were then stitched (i.e., merging video files together in a logical and preplanned fashion) together using an online platform called Stornaway (stornaway.io); as per the logic defined on the WDC CVS blueprint. For example, in the first scene of the WDC CVS, a nurse stating, "I'm going to gather my supplies and then I will be back to change your dressing" led to an option of the user to replay the video or continue onwards. The next segment of the WDC CVS began with the nurse returning to the bedside with the required supplies.

To facilitate realism within the WDC CVS, the researcher acted as the nurse and dressed in scrubs; and the co-researcher acted as the patient. The patient was situated on a hospital bed and wore a hospital gown and patient wristband. Next to the hospital bed was a bedside table used to set up the sterile field and position relevant WDC supplies. The wound was simulated by using a plastic abdomen model depicting a surgical wound and placed on the patient's abdomen.

WDC CVS Decision-making Point and Visual Aid Generation

Upon entering the WDC CVS, users are shown an introductory screen containing a brief description. Users are then prompted to click the "Begin Simulation" button. After each video plays, the user has the choice to replay the previous video or continue to the next. The WDC

CVS also contains (a) a decision-making point (DMP); and (b) a visual aid. In this study, the DMP allowed the user to choose between two equally correct methods to add an abdominal pad to the sterile field: (a) use the flipping method; or (b) use the green transfer forceps (Appendix D). The DMP was created to promote autonomy by empowering the user to foster their own unique nursing practice. This component was informed by the incentive system of game design for learning, drawing on the motivational elements that encourage players to continue their efforts (Plass et al., 2015). The visual aid is an image depicting a sterile field set up on a bedside table with all relevant WDC supplies (Appendix E). A green box was edited onto the image to delineate the sterile areas within the field; a red box was edited onto the image to delineate the non-sterile areas outside of the field. The visual aid was created to assist users in visualizing and conceptualizing the principles of sterility and its relationship to the sterile field. This component was informed by the visual aesthetic of game design for learning (Plass et al., 2015). Visual aesthetic design includes the overall visual elements and the form in which key information is represented, effectively combining cognitive function with aesthetics (Plass et al., 2015).

Unintended Realities of Video Recording the WDC CVS

In the third video segment of the WDC CVS, the nurse attempted to lay a rectangle-shaped sterile drape, flat on the bedside table. However, due to static cling on the drape at the time of recording, the drape would not fully deploy and remained slightly folded. The nurse then used the green transfer forceps to reposition the drape while maintaining sterility. Researchers discussed re-filming this scene as it did not depict the *ideal* process in which the drape would be placed onto the bedside table. However, researchers decided to use the video *as recorded* since the sterility of the drape was not compromised and the video captured a real-life, common practice occurrence (i.e., static cling on a drape) that can occur during a WDC.

Wound Dressing Change Clinical Virtual Simulation

A playable link to the WDC CVS created in this research study can be accessed at the following URL: https://player.stornaway.io/watch/e77411d4

Sample and Setting

This study used a non-probability convenience sampling approach to recruit participants from a large, urban university located in Southern Ontario (Canada). The inclusion criteria for the study included: (a) BScN student currently enrolled in any year of study (years one to four); or (b) nurse faculty clinical instructor currently teaching simulated practice. A total of seven participants were recruited (four BScN students and three nurse faculty clinical instructors). The sample size was informed by Rubin et al. (2008) who described that most problems related to usability are typically revealed after four to five participants have interacted with a product. Further, in previous research exploring the usability of a virtual simulation using TA methods, Luctkar-Flude et al. (2021a) used a similar sample size (i.e., six participants).

Data Collection

Once participants were recruited and had consented to participate in the study, a demographic questionnaire (Appendix F) was distributed via e-mail. Each participant attended a scheduled Zoom meeting to trial the custom WDC CVS on their personal computer or smartphone. A link was sent to the participant during the Zoom meeting to access the WDC CVS. Participants were asked to share their screen to allow the researcher to view their progression throughout the WDC CVS. During the WDC CVS trial, participants were asked to verbalize any thoughts that came to mind, as informed by the TA method (Ericsson & Simon, 1993). During the WDC CVS trial, researchers were only able to interact with participants during prolonged periods of silence to encourage them to keep talking (Ericsson & Simon, 1993). Researchers stated, “please keep talking” during prolonged periods of silence greater than approximately 30-45 seconds (Ericsson & Simon, 1993). Verbal data was audio-recorded and a Participant Observation Guide (Appendix G) was used to take notes during the WDC CVS trial. The WDC CVS trial lasted approximately five to ten minutes. Immediately after the trial, a short, individual, semi-structured interview was conducted on Zoom to allow participants to expand on their perceptions of the WDC CVS (Appendix H). The interviews were audio-recorded and lasted approximately 15 to 20 minutes. Open-ended probing was used to explore participants’ responses in greater depth.

Data Analysis

Data from the TA method and interview sessions were analyzed together. This decision was made to provide rich findings and was informed by previous studies that utilized similar data collection methods (Luctkar-Flude et al., 2021a). An inductive content analysis was conducted using the QSR NVivo 12 software. Data from the TA and interviews were transcribed verbatim and read multiple times to identify keywords and generate meaning units (Graneheim & Lundman, 2004; Hsieh & Shannon, 2005). The following is an example of a meaning unit derived from the collected data; “I didn’t realize how helpful it would be to see it in a first-person point of view (POV).” Meaning units were then condensed and labeled with a representative code (Graneheim & Lundman, 2004). For instance, the code “positive perception of POV” was created to represent the meaning unit in the previous example. The codes were compared to explore similarities and differences then grouped into categories (Graneheim & Lundman, 2004). Finally, through a process of reflection and interpretation, representative themes were formulated (Graneheim & Lundman, 2004; Hsieh & Shannon, 2005). In the example shared above, the theme of "*stepping into a nurse's shoes*" was created.

Enhancing Research Quality

Reflexivity

The purpose of this study is to explore the usability experiences of nursing students and faculty who trialed an in-house designed and developed CVS used to demonstrate a WDC. While the focus on this research was informed through conversations with my research supervisor, it is recognized that the topic of interest was likely also shaped by my past personal and professional experiences (Polit & Beck, 2021). Through purposeful reflexivity, I was able to critically reflect on my experiences, assumptions, and values, and recognize how they may have influenced the conceptualization of my research study (Polit & Beck, 2021).

Through personal critical reflection, I recognized that my interest and passion to explore the topic of technology-enabled learning and end-users' usability experiences began in my childhood home at the kitchen table. Each day after school, my younger brother and I would sit at the kitchen table and complete our homework. At this time, schoolwork did not come easy for my brother, he struggled immensely with reading and writing. This was an extremely stressful and emotional time for my entire family as we attempted to support him. After completing a psycho-educational evaluation, my brother was diagnosed with Dyslexia. My brother was introduced to new digital learning tools to support him through school. Some of the digital tools were fantastic, while others were not user-friendly in the slightest. My brother used to make jokes about how he planned to contact one of the companies and advise them to hire a person living with Dyslexia to trial the products before selling them. Since this time, and throughout the rest of my educational journey, I have continued to be intrigued by technology-enabled learning. From Kurzweil to Read&Write, I have attempted to find effective, accessible, and acceptable educational assistive technologies to support my own learning and that of my peers. Furthermore, from my past experiences, I can appreciate the importance of user-centred approaches thereby ensuring end-users are presented with effective, efficient, and enjoyable high-quality products.

During the COVID-19 pandemic, social distancing and stay-at-home orders demonstrated the importance of virtual-enabled and distance learning approaches in all fields of study, including undergraduate nursing education. With that in mind, I explored the literature related to virtual simulations in nursing education and began to make note of some of the gaps in knowledge and potential areas for further inquiry. I noticed that there was little research exploring wound care virtual simulations within nursing education. Drawing on this gap in knowledge, I developed and created a prototype WDC CVS to explore end-users' usability experiences of this technology-enabled learning method. In doing so, I hope to capture usability insights that can be leveraged to inform the successful development and integration of virtual simulations into undergraduate education to support the learning needs of future nursing students.

As a qualitative researcher, I situate myself within a constructivist paradigm valuing the subjective and multiple interpretations of reality (Weaver & Olsen, 2005). I apply this assumption to how I view user experience, in that it is individually constructed, unique, and dynamic. Throughout the research process, I engaged in reflexivity by means of self-reflection and reflexive writing to better understand myself and prevent my positionality from influencing the findings of my research (Polit & Beck, 2021).

Trustworthiness

To establish rigor within my study, I implemented the following four principles: credibility, dependability, confirmability, and transferability (Lincoln & Guba, 1985). Credibility was achieved through thick, detailed descriptions that illustrated participants' usability experiences of the WDC CVS (Bradshaw et al., 2017; Lincoln & Guba, 1985). Through meaningful engagement prior to and during interviews, I was able to establish a trusting rapport in which participants felt comfortable in disclosing information to me (Bradshaw et al., 2017). Confirmability in my research was established by carefully documenting my findings to facilitate transparency which allowed readers to understand my decision-making and reasoning (Bradshaw et al., 2017). This was facilitated through memoing and audit trails used to capture the data collection and analysis process (Bradshaw et al., 2017). Further, an abundance of direct participant quotes are shared to support the findings and themes presented in this research (Bradshaw et al., 2017). Dependability was achieved by disclosing any changes that were made to the original research proposal (Bradshaw et al., 2017). For example, in the original research proposal, this study was to focus on end-users' usability experiences toward a virtual simulation WDC facilitated using head-mounted display technology. However, due to social distancing and stay-at-home requirements, this research was facilitated through a computer-based application. Dependability was also fostered by practicing reflexivity and by acknowledging how my background, assumptions, and positionality may influence my research (Bradshaw et al., 2017; Lincoln & Guba, 1985). Finally, transferability was established by being transparent in the methods I used to conduct my research to allow for other researchers to replicate my study (Bradshaw et al., 2017).

Findings

Participant Characteristics

A total of seven participants were recruited for this study, four BScN student(s) (ST) and three nurse faculty clinical instructor(s) (CI). Five participants self-identified as female and two participants self-identified as male. The lowest level of education completed by participants was a high school diploma; two other participants had completed their BScN, and one other participant had completed a master's degree. All participants had previous experience performing a WDC in some capacity. One second year BScN student had only performed the skill in SBT on a manikin. Three third year BScN students had performed the skill in SBT and in clinical placement. Finally, all nurse faculty clinical instructors had extensive experience performing the skill in their professional nursing practice.

Results

Overall, four overarching themes were generated: (a) *overall CVS usability experience;* (b) *stepping into a nurse's shoes,* (c) *facilitating learning*; and (d) C*VS product and production.*

Overall CVS Usability Experience

All participants responded positively when asked about their overall thoughts related to the WDC CVS. Participants described the WDC CVS as "*cool* (CI2, CI4), *awesome* (ST5), *very valuable* (CI4), *easy to use* (ST1), *straightforward* (CI2, ST6), *and intuitive* (CI3)". Multiple participants also spoke about their preference for the first-person WDC CVS compared to third person videos. One student stated, *"For me, watching this first-person video is so much more in-depth than the third person video we currently watch"* (ST5). A clinical instructor stated, *"the difference in how helpful that* [referring to WDC CVS] *was compared to the traditional video we are watching right now, that* [referring to the third-person video] *is like a tutorial video on*

YouTube of people just doing a skill and it doesn't really feel personalized or engaging" (CI4). Finally, all participants stated that they would be interested in seeing more CVSs in future nursing education.

Stepping into a Nurse's Shoes

All participants spoke positively towards the first-person perspective that the WDC CVS offered. Most participants commented on the first-person perspective almost immediately during the WDC CVS trial. For instance, *"I like that you are actually seeing this from the nurse's perspective"* (CI4) and "*being able to see your arms as you got it* [sterile field] *ready was interesting*" (ST1). However, one clinical instructor commented multiple times about the length of the nurse's arms throughout the WDC CVS trial and how this was a distraction for them. Specifically, *"The arms are so long. It doesn't look real to me, but it could just be the way the video is"* (CI3).

Although participants were watching the WDC CVS on a computer screen, some shared that they felt the first-person view was effective in facilitating a more immersive learning experience. One student stated, *"I think it's so much more real feeling from the first-person view"* (ST5) and "*when you're ringing out the gauze, I felt like that was such a weird skill to learn... they did it so fast in the video* [referring to the third-person video BScN students are currently watching] *and it's hard to figure out...it was nice to see it in first-person"* (ST1). Further, a clinical instructor shared that *"it is interesting how I feel as if I'm the nurse doing it"* (CI3) and that the first-person view was valuable for *"students to watch it as if they are actually doing it as opposed to just watching it."* Another clinical instructor proposed that the first-person perspective could help students build confidence in their future role as a nurse, stating *"nursing students are always asking what it is really like to be a nurse and this virtual simulation offers a* *more authentic experience of being in the nurse's shoes compared to the current third-person tutorial video"* (CI4).

Multiple participants also spoke about the realism of the WDC CVS that was achieved by having a human patient compared to a simulation manikin. Students shared comments such as, *"I really like that component to facilitate patient interactions, that's so important"* (ST7); *"it's so nice having a real patient that's actually talking to you rather than a fake one"* and *"having an actual real patient that's looking at you and actually speaking to you it's totally different."* (ST5). A clinical instructor also spoke about the realism that was fostered by having the nurse in the WDC CVS speak to the patient as opposed to a voiceover narrating the video. For example, one clinical instructor stated that students struggle to approach patients and engage in conversation, especially with a simulation manikin and that *"listening to you* [referring to the nurse] *confidently talking to the patient"* (CI4) is valuable for students.

Facilitating Learning

All participants spoke positively about the DMP, describing it as *"engaging,"* (ST6) and *"the most valuable aspect of the simulation"* (CI4). Multiple students explained that they enjoyed having the ability to choose between two equally correct methods to add the abdominal pad to the sterile field, as opposed to deciphering the correct option from others that are incorrect. Some students stated, *"I'm glad that you showed both ways to add* [the sterile dressing to the sterile field] *because both are equally correct and its shows there is more than one way to do it correctly"* (ST5) and *"I like that there were two equal options to choose from so it was less intimidating in a way"* (ST1). Another student commented that having the DMP allowed them to exercise *"autonomy"* (ST6) in their nursing practice, an aspect they perceived was lacking in current SBT. Additionally, multiple participants suggested adding more challenging DMPs to test students' knowledge within the WDC CVS. For example, a clinical instructor suggested adding a DMP to test students' knowledge surrounding the wound exudate found on the patient's dressing (i.e., serous, sanguineous, serosanguinous, or purulent).

Multiple participants also spoke highly of the visual aid in the WDC CVS. Participants described how effective the visual aid was in demonstrating the *invisible sterile border*, often referred to when teaching aseptic procedures to nursing students. Participants described the visual aid as *"a great visual cue"* (ST7) and *"very helpful" (ST1)*. A clinical instructor stated, *"I particularly loved... that picture where the sterile field was laid out because I think it's something that's hard for individuals to kind of visualize.* (CI2).

Participants also identified an unintended learning opportunity within the WDC CVS. During the WDC CVS, the nurse attempts to lay the sterile drape flat on the bedside table; however, due to static the drape became positioned in a triangular shape. The nurse then uses the green transfer forceps to reposition the drape while maintaining sterility. Participants enjoyed this aspect of the WDC CVS, as they thought it promoted problem solving skills and demonstrated how to progress. Students commented, "*I think showing the little problem solving when your drapes aren't going where you want them to go is nice to see because they teach it so perfectly in the video we currently watch"* (ST1) and *"I think it's great that you are incorporating this because things don't always cooperate all the time"* (ST6). A clinical instructor explained that students in SBT often encounter situations like this and become overwhelmed, stating *"I like that the video is showing how you trouble shoot when things like this happen because often students freeze when this happens, and they don't know what to do"* (CI4).

Participants spoke about the potential to use the WDC CVS as a refresher to reinforce previously acquired knowledge. One student spoke about watching the WDC CVS to prepare for a skills exam, stating "*that's what I did with the other clinical skills videos, but I think this one* [referring to WDC CVS] *is a lot better and it's nice to see it from first-person"* (ST5). Another stated, *"I think in the summer a lot of second-year students are wondering how we are going to remember all of our lab skills in preparation for placement. So, I think these kinds of videos to look over before September would be a really great resource"* (ST6).

Both students and clinical instructors also commented on the potential time-saving ability of the WDC CVS. A clinical instructor stated, *"It's also short right. Students like things that are short and precise and to the point. They get bored, I think"* (CI3). Another clinical instructor shared similar perceptions, stating *"I liked that the video was short and engaging. Students get distracted and scroll through TikTok. This would keep their attention and it's not too long"* (CI4). The same clinical instructor also commented on the WDC CVS' ability to provide instructors with more time to teach students critical thinking skills, as opposed to focusing solely on hands-on skills. Specifically, "*if my students could use this POV video before class and come to class and actually be ready to apply this skill in real life it would give us so much more time in lab to discuss different contexts and things that may go wrong and to develop their clinical judgment rather than focusing on just acquiring the skill"* (CI4).

CVS Product and Production

All participants were able to load the interface and start the WDC CVS without requiring assistance from the researcher. All participants reported that the audio and video quality were sufficient. For instance, a clinical instructor stated that they could *"hear and see everything"*

(CI2). Multiple participants spoke highly of the video functionality including: the replay and pause options, the ability to look around the room, and zoom in during the WDC CVS.

In terms of technical issues, two participants identified brief periods of lagging or image pixelization due to their Wi-Fi connection. One participant stated, *"the pixelated picture is probably because of my bandwidth"* (CI4). Further, two participants reported that their laptops started getting warm during the WDC CVS and appeared to be *"working hard"* (ST 1,5*)*. One participant was able to resolve this problem by closing background activities and unused tabs in web-browser.

At the DMP, participants were required to select one of two options to add the abdominal pad to the sterile field. Once the selection was made, the corresponding video demonstrating the selected action was played; however, there is currently no ability to return to the DMP screen and select the other option. Multiple participants commented on this and said that being able to go back and choose the other options would be helpful in learning different techniques. For instance, one participant commented, *"It would have been nice to go back and see what it would have looked like if I picked the alternative way"* (ST1). Finally, a few participants commented on the camera's movement, specifically during the scene when the nurse is adjusting the bedrails. Participants described this scene as *"wobbly"* (ST6), and that the camera was moving *"fast"* and *"awkwardly"* (CI3).

Moreover, some participants spoke about the potential that the computerization of simulations offers for learners. A student and clinical instructor talked about how future prototypes could use digitalization to demonstrate very realistic wounds. The student stated, "*when it's coded the end is nowhere, you can code anything. You can make a wound look as bad as possible, show necrosis*." (ST4). Finally, two participants spoke about how a real patient with a fake wound (displayed on a manikin abdomen) created a lack of realism in the WDC CVS. For example, one participant stated, *"a barrier was that you used a manikin wound on a real patient so that created a lack of realism in my mind"* (CI3). Both participants stated that they would prefer congruency between the patient and the simulated wound. For instance, *"if you are going to use an incisional manikin body part you should use a manikin as the patient. If by chance you are using a human, although it would be difficult, but to have a real incision if possible"* (CI3) and "*if you have a fake wound then maybe you should use a manikin, and if it's a real patient like this simulation, then mimic a real wound*" (ST6).

Discussion

The purpose of this study was to explore nursing students' and nurse faculty members' usability experiences toward a prototype level WDC CVS. Understanding nursing students and nurse faculty members' experiences of usability is a critical aspect of user-centered CVS development (Mandel, 2003). Several themes emerged from the findings of this study pertaining to the usability of the WDC CVS, including (a) *overall CVS usability experience;* (b) *stepping into a nurse's shoes*; (c) *facilitating learning*; and (d) *CVS product and production.*

Overall, participants' experiences related to the usability of the WDC CVS were positive. Both nursing students and nurse faculty members described the virtual simulation as enjoyable and would be interested in incorporating this learning method into future education. These findings were consistent with previous studies exploring the use of virtual simulation amongst nursing students (Breitkreuz et al., 2021b; Butt et al., 2018; Kardong-Edgren et al., 2019; Kim et al., 2021; Luctkar-Flude et al., 2021a; Silva et al., 2019; Verkuyl et al., 2016). Participant-perceived realism was highlighted in this study as a key aspect related to positive usability experiences. The use of a realistic patient scenario, filming in the simulation suite, and dialogue between the patient and nurse, were factors identified by participants as key aspects contributing to realism and immersion within the WDC CVS. Researchers in the present study were intentional about facilitating a high level of realism in the WDC VRS, as previous research has demonstrated that virtual simulations containing static video or animation can be perceived by students as not realistic and "cheesy" (MacRae et al., 2021, p. 30). Further, evidence is emerging that demonstrates a positive relationship between realism, presence, and learning outcomes for nursing students in highly immersive simulations (MacRae et al., 2021). Therefore, highly immersive and realistic design and recording elements should be prioritized when creating and developing future CVS to enhance end-users' usability experiences.

In addition to filming in a simulated hospital setting, realism was also facilitated by recording in the first-person perspective. Multiple participants spoke positively about the first-person perspective and stated that they felt as if they were *"actually performing"* the WDC as opposed to simply watching a demonstration. Due to technological limitations, traditional nursing skill demonstration videos have been limited to a third-person perspective (Shibuya et al., 2019). Research conducted by Brechet et al. (2019), found that episodic memories, "recollections of contextually rich and personally relevant past events", have been linked to bodily self-consciousness which may be enacted during participation in first-person virtual environments (p. 1). These findings are consistent with previous research exploring first- and third-person perspectives in immersive virtual environments (Gorisse et al., 2017). For example, Gorisse et al. (2017) conducted a quantitative study exploring the impact of first and third-person viewpoints in immersive environments. Results demonstrated that a first-person perspective appeared to possess "a favorable and superior impact to third-person on the sense of self-location (volume of space in which the user feels located) and the sense of ownership (one's self-attribution of a body)" (Gorisse et al., 2017, p.7). When observing an action from third person, the learner must mentally translate the action into a first-person perspective (Ros, 2019). Although humans can do this, significant "cognitive load is required, which can be reduced by using a first point-of-view while demonstrating a task" (Ros, 2019, para. 4). Specifically, viewing a demonstrator's hands and arms provides viewers with more detailed information about the actions performed (Shibuya et al., 2019). This finding was highlighted in the following quote from a nursing student interviewed in the present study; "*when you're ringing out the gauze, I felt like that was such a weird skill to learn... they did it so fast in the video* [referring to the 3rd person video BScN students are currently watching] *and it's hard to figure out...it was nice to see it in first-person"* (ST1). Based on the findings presented by Ros (2019), and the results of the current study, to enhance the effectiveness of virtual simulations, developers should consider filming demonstration videos from a first-person perspective while including hand and arm movements in the user's field of view.

Further, the WDC CVS contained a DMP that allowed users to choose between two equally correct methods to add an abdominal pad to the sterile field. Participants shared that they thought the WDC CVS was effective in promoting professional autonomy and clinical decision-making by allowing students to select from equally correct options; whereas most simulations contain skill testing questions designed to have students select the correct response by eliminating incorrect options (Verkuyl et al., 2022). Verkuyl et al. (2022), reported similar findings in a study evaluating users' experiences of a virtual simulation. Participants in the study noted that game-generated responses to DMP reduced their autonomy and sense of mastery;

however, participants perceived that free-text responses promoted professional autonomy (Verkuyl et al., 2022).

In the present study, there is a scene where the sterile drape folds onto itself and the nurse must use the transfer forceps to reposition the drape appropriately. Researchers discussed re-filming this scene but decided against it as the nurse was able to maintain the sterility of the sterile drape. Multiple participants identified this scene as valuable and effective as it depicts *"problem-solving"* or *"trouble-shooting"* in a manner not often captured in SBT. Participants commented that in past SBT material used in their education, idealistic processes are shown where a nurse completes a clinical skill flawlessly. Participants commented that when a nursing student encounters a deviation in their own practice, compared to what they observed in the SBT material, they are often flustered and unsure how to progress. In a study conducted by Finley (2020), exploring perfectionism, 57.6 percent (n = 61, 57.6%) of nursing students (N = 106) identified into the maladaptive perfectionist category. Maladaptive perfectionism is associated with excessive worry about performance, stress, anxiety, and self-blame (Finley, 2020). Perhaps participants in the present study gravitated toward this scene as it depicted genuine nursing practice and an aspect of realism that may closely resemble their own experiences. Previous research has demonstrated that learner "engagement is enhanced by authentic representation of clinical situations" (Luctkar-Flude et al., 2021, p. 324). Incorporating the findings from the present study, realism in simulation can be facilitated through traditional methods (i.e., real patients, filming in realistic environments) but also by sharing the realities of being a nurse and moving away from idealizing perfectionism in practice.

In addition to the positive findings that emerged in the present study, it is imperative to also discuss the areas of usability improvement. The only technical issue reported in the present study was temporary freezing or lagging of the WDC CVS. This is a common issue described in previous studies exploring CVS in nursing education (Breitkreuz et al., 2021a; Breitkreuz et al., 2021b; Butt et al., 2018; Lee et al., 2020; Luctkar-Flude et al., 2021b; Verkuyl et al., 2016). Although in the present study, this issue only lasted a few seconds and was easily resolved, considerable literature has demonstrated that technical issues can decrease learning opportunities (Verkuyl et al., 2022). Therefore, it is crucial that nurse educators ensure students have access to technical resources and support (Verkuyl et al., 2022), and adequate bandwidth to ensure efficiency of the WDC CVS (Crane et al., 2021).

Based on the findings collected in the present study, future revisions to the WDC CVS are warranted. For instance, participants spoke about the potential of incorporating complicated wounds (i.e., necrotic wounds) into the WDC CVS. This type of CVS advancement may require an interdisciplinary approach, combining nurse educators' wound care background with the expertise of a computer software professional to virtualize more complex and realistic wounds. As CVSs become more prominent across nursing education, nurse researchers have discussed the importance of including web-designers in the creation of user-friendly and customized CVSs (Lee et al., 2020).

Strengths and Limitations

This research had several key strengths. Firstly, the rigorous qualitative approach implemented was useful in collecting rich insights pertaining to nursing students' and nurse faculty members' usability experiences. These findings can be leveraged to improve future WDC CVS prototypes. Further, the utilization of the TA method allowed researchers to collect information from participants' STM that may have otherwise been lost prior to the subsequent interview taking place.

This research also sheds light on several findings that have been hitherto underexplored. Firstly, this study highlighted the importance of usability exploration within the nursing educational domain, an area of research that has only recently come about in nursing literature; however, of the utmost importance to ensure nursing students are provided with high quality learning opportunities. Secondly, this study focused on wound care education, a skill identified in nursing literature as an area requiring further support and refinement in nursing education, and an area poorly explored in virtual simulation literature. Moreover, this study included nurse faculty members' usability experiences toward the virtual simulation, a population currently understudied. Next, the results of this study draw attention to the perceived benefits of first-person virtual simulation, including the visualization of the demonstrator's hands and arms when completing tasks.

Further, this study is the first of its kind (to our knowledge) to document the incorporation of *all correct options* in DMPs, resulting in participants' perception of exercising autonomy and clinical decision-making. Additionally, in the present study, there is a scene where the sterile drape folds onto itself and the nurse must use the transfer forceps to reposition the drape appropriately. Researchers discussed re-filming this scene but decided against it as the nurse was able to maintain the sterility of the sterile drape. To the researchers' knowledge, this is the first study highlighting participants' positive perceptions toward a *less than perfect* demonstration of a nursing skill. Incorporating this finding into future virtual simulations may promote pragmatic problem-solving that students can apply to nursing practice.

Finally, the findings from the current study further reinforce the need for nurse simulation developers to collaborate with web-designers to mitigate some of the technological issues commonly reported by participants. Lastly, one of the key strengths of this research is the detailed description of the methodology utilized to create the WDC CVS. This study outlined the workflow process, recording template, and technology used by researchers to facilitate the WDC CVS development. This information systematically illustrates the steps required to develop CVSs and may serve as a roadmap for future nurse simulation developers.

Although this research contained many strengths, there are several limitations that should be considered when interpreting the findings and implications of this study. A qualitative descriptive methodology was used to explore nursing students' and nurse faculty members' usability perceptions of the WDC CVS at one Canadian university, limiting the transferability of the findings. Moreover, it is possible that the participants who entered this study may have had a high affinity for technology, potentially underrepresenting the experiences of those with a low affinity for technology. Finally, the sample in this study was small and consisted of participants who had previously completed a WDC in some capacity (i.e., lab/simulation, clinical placement, or professional nursing practice). Therefore, the findings of this study may not reflect the experiences or perceptions of a new learner (i.e., a first-year nursing student who has never completed a WDC) and should be interpreted with caution.

Conclusion

Four themes emerged from the data pertaining to nursing students' and nurse faculty members' experiences and perceptions toward the usability of the WDC CVS: (a) *overall CVS usability experience;* (b) *stepping into a nurse's shoes*; (c) *facilitating learning*; and (d) C*VS product and production.*

Overall, nursing students and nurse faculty members shared positive experiences toward the usability of the WDC CVS. Participants spoke highly of the degree of realism and immersion they experienced from the first-person perspective. The DMP was also perceived positively by both students and CIs. Participants stated that they enjoyed the perceived autonomy that was fostered by allowing users to choose how to proceed throughout the WDC CVS. Based on the feedback provided, participants stated they wanted more DMPs to be incorporated into the WDC CVS, in addition to including more challenging DMPs. Multiple participants also commented on the problem-solving/troubleshooting aspect that was demonstrated when the nurse attempted to place the sterile drape on the bedside table. This scene demonstrated the nuances of video filming; however, participants praised this scene for its realism and depiction of the realities of genuine nursing practice. Finally, a few participants experienced minor technical issues including freezing or lagging of the simulation videos; however, this issue did not last long and was easily resolved by refreshing the webpage. The valuable insights pertaining to end-users' usability experiences will be incorporated into the next WDC CVS prototype.

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CHAPTER THREE

The purpose of this study was to explore the usability experiences of nursing students and faculty who trialed an in-house designed and developed clinical virtual simulation (CVS) used to demonstrate a wound dressing change (WDC). This chapter discusses implications for nursing research and education informed by the results of the present study.

Implications for Nursing Research

New generation nursing students have grown up in a digital era where technology is profoundly rooted in all aspects of their lives, including education (Luctkar-Flude et al., 2021a; Padilha et al., 2018). Nurse researchers and educators must acknowledge the shift to technology-enabled learning and explore modalities that capture students' attention, support professional development, and optimize learning opportunities (Padilha et al., 2018). One proposed solution includes the implementation of virtual simulation; however, prior to widespread adoption into nursing education, exploring the usability experiences of end-users' is imperative.

The results of this study suggest that there are opportunities for educational institutions to leverage virtual simulation within nursing curricula to support wound care education. However, further revisions are required prior to implementation. Using the results of the present study, researchers plan to develop a second WDC CVS prototype and further explore end-users' usability experiences with a larger sample size and across multiple educational institutions to promote transferability (Butt et al., 2018). Further, the findings from the current study reinforce the need for nurse simulation developers to work with web-designers to mitigate some of the technological issues commonly reported by participants to improve the usability of virtual simulations (Crane et al., 2021). To accomplish this, nurse researchers should collaborate with web and software designers to support the creation of highly realistic, user-friendly, and customizable virtual simulations (Lee et al., 2020; Verkuyl et al., 2018).

Next, nurse researchers should conduct quantitative usability testing to objectively assess outcomes related to the use of virtual simulations. For example, nurse researchers in the present study plan on using validated measurement tools such as the *System Usability Scale* to measure the usability of the WDC CVS as perceived by nursing students and nurse faculty members (Butt et al., 2018). Additionally, research is also required to assess the effectiveness of the WDC CVSs in relation to student specific learning outcomes and knowledge retention (Breitkreuz et al., 2021a; Crane et al., 2021).

It is also important to acknowledge the imperative role that nurse faculty members play in the development of effective, efficient, and enjoyable high-quality virtual simulations. Nurse educators possess valuable insights pertaining to best practices in SBT that ought to be incorporated into virtual simulations to ensure products are useable from an educator's perspective. Thus, it is crucial that nurse researchers prioritize recruiting nurse faculty members when exploring end-users' usability experiences related to virtual simulations.

Finally, nurse simulation developers require guidance in developing in-house virtual simulations. Nursing literature describing explicit protocols related to the development of in-house virtual simulations are difficult to locate, leaving developers with little support. Recently, the Canadian Association of Schools of Nursing (2022), published *Virtual Simulation: An Educators Toolkit*, a resource designed to assist nurse educators implement virtual simulation into nursing curricula. However, this resource focuses on the implementation of commercial virtual simulation. Although the present research focused on wound care education, this study provides a roadmap that can be leveraged by other nurse researchers who are interested in developing virtual simulations.

Implications for Nursing Education

SBT is a fundamental teaching-learning strategy used in nursing education to promote nursing students' acquisition of hands-on skills, critical thinking, and professional judgment in a safe and controlled environment (Aebersold, 2018; Madden & Carstensen, 2019). More recently, due to advances in technology and the current generations' preference for digitally enabled learning (Padilha et al., 2019), virtual simulations have become a topic of high interest in nursing education (Roberts et al., 2019). Further, due to high nursing student enrollment and decreases in nurse faculty members, some institutions have begun substituting clinical practice hours for increased SBT (Roberts et al., 2019). For instance, the National Council of State Boards of Nursing (Wolters Kluwer, 2017), "found that up to half of traditional clinical hours in pre-licensure nursing programs can safely be replaced by high-quality patient scenarios for students in the form of nursing simulations" (para. 3), including the use of virtual simulations. As such, well-developed and effective virtual simulations are imperative to ensure nursing students are provided with ample opportunity to foster their nursing knowledge and prepare them for entry to practice. As virtual simulations become more prevalent in SBT, care must be taken to ensure that they are user-centred and support the needs of nursing students.

The present study included nurse faculty members as participants to elicit important insights related to the WDC CVS' usability from an educator's perspective; however, further research is warranted to explore how nurse educators can actively participate in facilitating the successful integration of virtual simulations into nursing curricula. According to Verkuyl et al. (2021), engaging nurse faculty members facilitates their "connection to the virtual simulation and makes them champions of its uptake" (p. 3). Seeking feedback from educators through usability exploration provides opportunities to improve the virtual simulations to enhance both faculty and student experiences (Verkuyl et al., 2021). Therefore, it is imperative that nurse educators are actively involved in structuring nursing curricula to include virtual simulations as a pedagogical approach.

Summary

The findings of this study demonstrate that nursing students and nurse faculty members who participated in this study had positive experiences related to the usability of the WDC CVS. This research contributes to the growing body of nursing knowledge related to virtually enabled SBT and adds important insights related to the usability of virtual simulations to facilitate wound care education, an area currently under studied in nursing science. The findings from this study will be used to make improvements to the WDC CVS prior to further exploration with end-users. Finally, although in its infancy, this research provides a roadmap that can be leveraged by other nurse simulation developers when creating in-house virtual simulations.

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APPENDICES

Appendix A: Ethics Certificate

Western Research

Date: 10 January 2022

To: Dr. Richard Booth

Project ID: 119989

Study Title: Virtual Reality Simulation (VRS) in Clinical Nursing Education: A Qualitative Usability Study

Application Type: HSREB Initial Application

Review Type: Delegated

Full Board Reporting Date: 25/January/2022

Date Approval Issued: 10/Jan/2022

REB Approval Expiry Date: 10/Jan/2023

Dear Dr. Richard Booth

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above mentioned study as described in the WREM application form, as of the HSREB Initial Approval Date noted above. This research study is to be conducted by the investigator noted above. **All other required institutional approvals and mandated training must also be obtained prior to the conduct of the study**.

Documents Approved:

Document Name	Document Type	Document Date
Appendix C Semi-Stuctured Interview Guide_SC	Interview Guide	10/Nov/2021
Appendix D CTA Observation Data Collection	Participant Observation Guide	10/Nov/2021
Appendix E Demographic Information	Other Data Collection Instruments	Received January 5, 2022
Appendix G_Recruitment email version 2	Email Script	03/Dec/2021
Appendix A Research Protocol version 2	Protocol	03/Dec/2021
Appendix H_LOI+C version 2	Written Consent/Assent	04/Jan/2022

No deviations from, or changes to, the protocol or WREM application should be initiated without prior written approval of an appropriate amendment from Western HSREB , except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University HSREB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Karen Gopaul , Ethics Officer on behalf of Dr. Emma Duerden, HSREB Vice-Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Appendix B: Wound Dressing Change Workflow Diagram

<table>
<tr><td colspan="2">Verify physician's order for wound dressing change.</td></tr>
<tr><td colspan="2">Gather supplies.</td></tr>
<tr><td colspan="2">Introduce yourself to patient and perform hand hygiene (HH).</td></tr>
<tr><td colspan="2">Identify patient (pt) using two identifiers.</td></tr>
<tr><td colspan="2">Perform pain assessment. Does pt have pain related to wound?</td></tr>
<tr><td>Yes.</td><td>No.</td></tr>
<tr><td>Pre-medicate pt. Reassess pain.</td><td>Proceed to next step.</td></tr>
<tr><td colspan="2">Remove extraneous items from pt's bedside table (BT).</td></tr>
<tr><td colspan="2">Position pt (lower side rails, raise bed,) and expose old dressing.</td></tr>
<tr><td colspan="2">Verify sterile solution expiration date.</td></tr>
<tr><td colspan="2">HH.</td></tr>
<tr><td colspan="2">Place dressing tray on the side of the BT closest to the pt. Open tray by grasping one corner and opening peel pack away from your body.</td></tr>
<tr><td colspan="2">Remove green transfer forceps (GTF) and pick up garbage bag from tray. Place sterile steel on BT. Rest GTF with tips inside the sterile boarder of the sheet.</td></tr>
<tr><td colspan="2">Position garbage bag in a manner that allows for easy access and does not require turning back to sterile field (end of pt's bed).</td></tr>
<tr><td colspan="2">Use GTF to pick up sterile drape, grasping one side with fingers in the outer 1-inch boarder and position on BT w/ shiny side down.</td></tr>
<tr><td colspan="2">Use GTF to pick up the white sterile drape & blue sterile drape and place in the center of the sterile field.</td></tr>
<tr><td colspan="2">Use GTF to position metal forceps. Place each (two) of the metal forceps in the small compartment sections of the tray.</td></tr>
<tr><td colspan="2">Place GTF with sterile tips past the 1-inch boarder of the sterile field w/ handle on table.</td></tr>
<tr><td colspan="2">Add sterile solution (0.9% normal saline) to the sterile tray.</td></tr>
<tr><td colspan="2">*Decision-making point*
Add sterile abdominal pad to the sterile field.</td></tr>
<tr><td>Open package away from body and use flipping technique to drop item onto field.</td><td>Open package away from body and use GTF to remove item from package. and place on field.</td></tr>
<tr><td colspan="2">Don clean gloves.</td></tr>
<tr><td colspan="2">Remove pt's soiled dressing and assess wound drainage.</td></tr>
<tr><td colspan="2">Remove gloves & HH.</td></tr>
<tr><td colspan="2">Use GTF to pick up white sterile drape and place shiny side down between pt's wound and BT table. Dispose of GTF.</td></tr>
<tr><td colspan="2">Use sterile forceps to pick up sterile gauze and moisten in sterile solution. Wring out excess moisture.</td></tr>
<tr><td colspan="2">Cleanse wound in the following order:
1. Incision line
2. Far side
3. Near side</td></tr>
</table>

Assess wound. Determine the integrity of the wound. Ensure all staples/sutures are intact by counting and documenting quantity. Assess for presence of dehiscence.
Use sterile forceps to place new dressing over wound. Tape to secure.
Dispose of materials and perform HH. Sterile forceps should be placed in the sharps.
Reposition pt, ensuring beside rail is up and bed is lowered.
HH.

Appendix C: Wound Dressing Change Recording Template

Recording logistics:

- GoPro chest mounted
- Record in 360 degrees, 4k resolution
- Front camera cap off
- Back camera cap on

Video editing logistics:

- In GoPro player (desktop application) – turn world lock on. *World lock* sets the orientation of the view, leveling the video, and minimizes rotation.

Steps/Title	**Video Cues**
Wound Dressing Change Clinical Virtual Simulation *short explanation on screen explaining how the simulation works (i.e., click and drag on the screen to change your point-of-view; decision-making points will appear on the screen use the mouse to click your option)	On screen prompt: “Begin Simulation”
Scene 1: Nurse: Good morning, how are you? Patient (pt): Good how are you? Nurse: I’m good. My name is Sam and I’m going to be your nurse today. Today I am going to be performing a wound dressing change on your surgical wound. Does that sound ok? Pt: That’s great. Nurse: Can you tell me your first and last	*nurse walks into room and performs hand hygiene (HH) by using the sanitizer on the patient’s bedside table

name? Pt: Carl Simmons Nurse: And your date of birth? Pt: 15th October 1980 Nurse: I am going to gather my supplies and then I will change your dressing.	*checks pt identity using two identifiers *scene ends On screen prompt: "Gather supplies" or "Replay"
<u>Scene 2:</u>	*photo of each supply required *Dressing tray* *NaCl bottle* *Abdominal pad* *Tape* *Clean gloves* On screen prompt: "Return to simulation" *scene ends
<u>Scene 3:</u> Nurse: Okay, I have all my supplies now. Are you able to tell me if you had any pain the last time you had your dressing change?	*supplies will be placed on the far end of pt's bedside table *nurse HH *nurse uses wipe to clean pt's bedside table *nurse adjusts bedside table to working

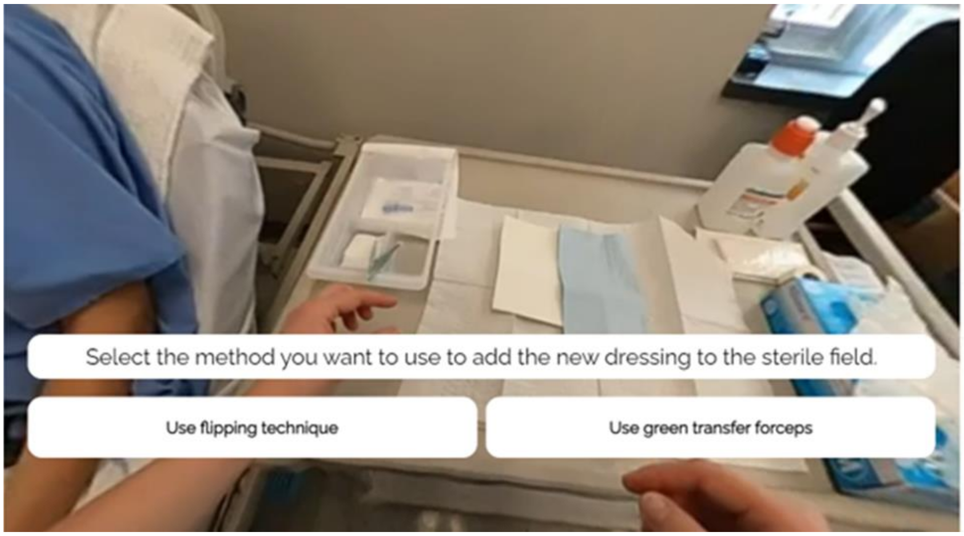
Pt: No, I didn't have any pain. Nurse: Okay great. Now I'm going to adjust the bed and put the railing down and expose your wound. I'm going to start to set up my sterile field – I'm going to ask you to stay in this position.	height *raise bed, lower side rail *expose covered wound *scene ends On screen prompt: "The Ins and Outs of the Sterile Field" or "Replay"
Scene 4:	*photo of sterile field *sterile field photo with color indicators appears with an explanation of the sterile field On-screen text: The green box shows the sterile field. Notice how the green forceps tips are placed within the sterile field. These tips must remain sterile in order to add items onto the sterile field. The red box (and beyond the red box) shows the areas that are not sterile. Notice how the arms of the green forceps are not within the sterile field. This allows the nurse to continue to use the forceps without contaminating the sterile field. On screen prompt "Continue"
Scene 5:	*nurse HH *open dressing tray - place on bedside table closest to pt *use green forceps to remove the garbage bag *place sterile forceps in tray so tips remain

	sterile *position garbage bag at end of pt's bed *use green forceps to pick up sterile drape - use finger to grasp drape and place on table shiny side down *use green forceps to place the blue and white drapes onto the white drape *scene ends On screen prompt: "Continue" or "Replay"
Scene 6:	*use green forceps to stand the metal forceps up in the tray *place green forceps down on the drape with tips sterile On screen prompt *decision-making point* "Select the method you want to use to add the new dressing to the sterile field" A. Use flipping technique B. Use green transfer forceps *selected options plays* *scene ends On screen prompt: "Continue"
Scene 7:	*nurse opens sterile saline and adds it to the sterile field *scene ends On screen prompt: "Continue" or "Replay"
Scene 8: Nurse: I am going to remove the old dressing	

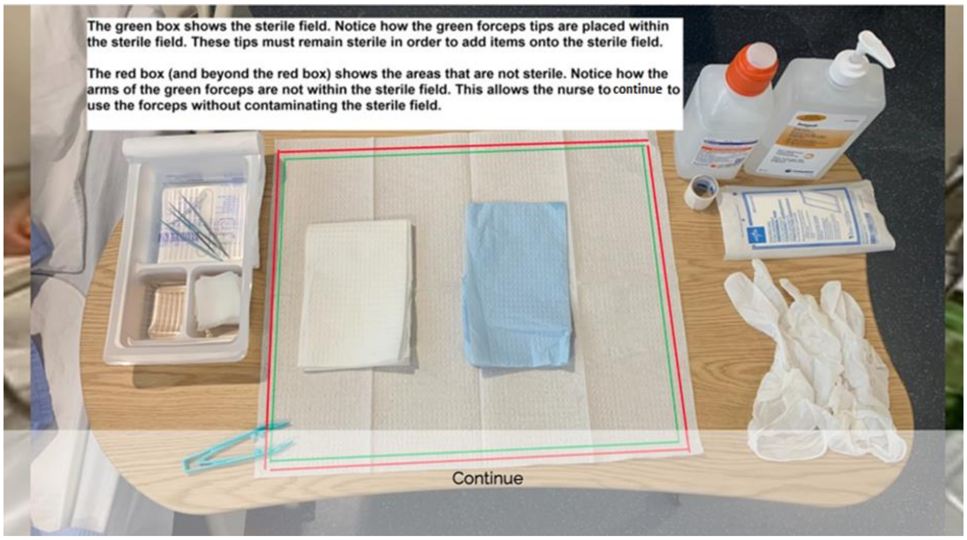
now. Let me know if you experience any discomfort. Pt: Okay.	*put on clean gloves *remove dressing and show to camera *assess the drainage *discard old dressing *remove gloves and HH *scene ends On screen prompt: “Continue” or “Replay”
Scene 9:	*use green forceps to pick up white drape and place shiny side down between table and pt’s wound site *place green forceps in the garbage *use silver forceps to moisten 2x2 gauze with saline and wring out *clean wound *discard moistened gauze into garbage *scene ends On screen prompt: “Continue” or “Replay”

Scene 12: Nurse: I'm going to apply your new dressing now.	*use sterile forceps to place new dressing on wound *secure with tape *cover pt, bedside rail up, and discard supplies *metal forceps in the sharps container *scene ends On screen prompt: "End simulation" or "Replay"

Appendix D: Decision-Making Point within Clinical Virtual Simulation



Appendix E: Sterile Field Visual Aid within Clinical Virtual Simulation



Appendix F: Demographic Questionnaire

Please indicate the appropriate response with **X** or fill in the blank.

1. Gender: __________

2. Highest educational level completed:

a) Highschool diploma ____

b) University Undergraduate ____

c) University Master ____

d) University PhD ____

e) Other: ________________________

3. Have you had any previous experiences performing a simple wound dressing change?

Y_____ N_____

If yes, please describe.

____

4. Have you had any previous experiences using virtual reality technology in any capacity?

Y____ N_____

If yes, please describe.

____

Appendix G: Observation Guide

Section One: Starting CVS	Participant's Comments	Researcher Notes
Section Two: Intra-CVS	**Participant's Comments**	**Researcher Notes**

Appendix H: Semi-Structured Interview Guide

1) What are your overall thoughts on the virtual simulation?
2) What was it like to get started with the virtual simulation?
    a. What would you suggest adding/removing to improve the starting process?
3) How would you describe the visual quality of the virtual simulation?
4) How would you describe the audio quality of the virtual simulation?
5) What are your thoughts on the decision-making point?
6) Did you experience any technical problems?
    a. What were they?
    b. How did you resolve the problem?
7) Learnability is defined as the ease and speed with which a user gets familiar with the use of a new product.
    a. How would you describe the learnability of the virtual simulation?
8) Would an activity like this be useful to you/ your students when preparing for clinical placements?
    a. Why or why not?
9) What recommendations can you propose to make the simulation more interesting?
10) Is there any other feedback that you would like to provide?

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