EXPLORING THE USABILITY OF GAME-BASED VIRTUAL REALITY FOR DEVELOPMENT OF PROCEDURAL SKILLS IN UNDERGRADUATE NURSING STUDENTS

by

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A dissertation

submitted in partial fulfillment

of the requirements for the degree of

Doctor of Education in Curriculum and Instruction

Boise State University

May 2015

BOISE STATE UNIVERSITY GRADUATE COLLEGE

DEFENSE COMMITTEE AND FINAL READING APPROVALS

of the dissertation submitted by

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Dissertation Title: Exploring the Usability of Game-Based Virtual Reality for Development of Procedural Skills in Undergraduate Nursing Students

Date of Final Oral Examination: 04 May 2015

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DEDICATION

To my family, especially my husband, Darryl, who helped me eat this elephant even though there were times I felt like I’d had more than enough.

To my students who inspire me every day to look for better ways to learn with them.

And to my partner, Jayne—we got into this together and we made it through, together.

ACKNOWLEDGEMENTS

Thanks to my dissertation committee for your time, wisdom, encouragement, and guidance through this adventure. Obviously, I couldn't have finished without your help. Dr. Keith Thiede, this entire process has been an unforgettable *Academic Celebration,* start to finish; thanks for helping me navigate it successfully. Dr. Suzan Kardong-Edgren, you've inspired me in countless ways in the short time I've had the pleasure of calling you my friend and mentor, thank you. Dr. Karen Breitkreuz, you loaned me your favorite mixed methods book when I was still in denial that I really needed to do mixed methods; thanks for your calm reassurance that I would get this done and life would go on. And Dr. Chris Haskell, though *virtual reality* may be a deprecated term, thanks for your willingness to discuss it and encouragement to intentionally think about how I was using it.

Thanks to my doctoral cohort, this wouldn't have been nearly as much fun without each of you; in fact, there's a good chance it wouldn't have been much *fun* at all.

Thanks to my colleagues in the School of Nursing for your unending support and words of encouragement even when I whined—sometimes a lot. I know how lucky I am to consider you my friends.

Finally, thanks to my parents, my husband, and to my kids, Alicyn, Jessica, and Mitchell, for being my biggest fans.

ABSTRACT

Providing safe, high quality patient care requires that undergraduate nursing students learn and apply extensive content knowledge as they also begin to develop clinical judgment. Nursing students must learn several procedural skills and be ready to remember and competently perform these skills when the need arises during patient care. Some procedures require strict adherence to aseptic technique in order to protect patients from hospital-acquired infections. Consequently, nurse educators are challenged to find innovative and interactive ways to help students develop and remember these important fundamental skills while ensuring patient safety.

This study used a mixed methods design to explore the usability of, and user-reaction to, a game-based virtual reality (VR) system. The unique system combines headgear and haptics to place the nursing student *in* a patient's room in order to practice inserting a urinary catheter virtually. The study also compared control and experimental participants' time-on-task, number of procedures completed in one hour, and ability to demonstrate aseptic technique during urinary catheter insertion two weeks post-practice session.

All study participants were given one hour to practice catheter insertion, either on a task trainer or virtually. User reactions to the VR game were observed during gameplay and collected via survey immediately after each individual VR game practice session. Subjects rated the system solidly in the *Acceptable* range using the System Usability

Survey (Brooke, 1996) and between *Good* and *Excellent* when including a comparative adjective rating scale (Bangor, Kortum, & Miller, 2009).

Inclusion of minimal game elements (points and a timer) motivated participants to continue to practice in order to improve their scores and procedure completion time, as well as engage in competition against their peers. Subjects in the experimental group spent more time practicing and completed more procedures than subjects in the control group and rated the experience as highly engaging and enjoyable. The pass rate at two week follow-up catheter insertion demonstration was 60% for both groups.

Results of this study suggest that combining VR technology with game-based learning provides an innovative and useful way for students to practice procedural skills prior to performing the procedure on patients. The next iteration of the system will include an emphasis on providing clearer feedback to promote more accurate practice and should then be tested on larger numbers of students at multiple sites.

Key words: Nursing education, procedural skill, virtual reality, gaming, game-based learning, simulation, immersive technology, deliberate practice, experiential learning.

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LIST OF ABBREVIATIONS

GBL	Game-Based Learning
SBE	Simulation-Based Education
SON	School of Nursing
SUS	System Usability Survey
VR	Virtual Reality

CHAPTER ONE: INTRODUCTION

Providing safe and high quality patient care requires that undergraduate nursing students learn and apply extensive content knowledge as they also begin to develop clinical judgment. Nursing students must learn several procedural skills and be ready to remember and competently perform these skills when the opportunity arises during patient care. Some of these procedures, including urinary catheter insertion, require strict adherence to aseptic technique in order to protect patients from nosocomial or hospital-acquired infections. Consequently, nurse educators are challenged to find innovative methods to help students develop and remember these important fundamental skills while ensuring patient safety.

Background

Insertion of a urinary catheter is one of the most frequently performed and potentially harmful procedures nursing students are expected to learn and implement as needed during patient care. Students are typically expected to learn this procedure early in their nursing education, along with numerous other procedural and psychomotor skills. Traditionally, various methods and combinations of methods have been used to teach the procedure. Students may:

- listen to a lecture,
- read about the procedure,

- watch a video and/or live demonstration of the procedure on a simulated task trainer (designed specifically to assist learners to practice and master a particular task, in this case, catheter insertion), and finally,
- practice the procedure on a task trainer using a procedural checklist with feedback from faculty experts or, in some cases, more experienced peers. (Gunberg Ross, Bruderle, & Meakim, 2015)

Students' hands-on practice of the requisite psychomotor skills in the lab is limited by lab availability and immediate, constructive feedback may be limited by increased faculty-to-student ratios. Additionally, depending on the faculty member and his/her experience, there may be wide variety in the feedback that learners receive about the *best* way to complete the procedure. After practicing, students are expected to demonstrate competence, sometimes loosely defined as the ability to perform the skill "correctly" on *this* day in front of *this* faculty member. Students demonstrate the procedure on a task trainer using the equipment they practiced with while faculty grade their performance using a criterion-based checklist traditionally utilized in nursing education (Bjork, 1997; DeBourgh, 2011; Gonzalez & Sole, 2014). If a student has difficulty, faculty may ask the student to practice further before returning for another attempt or actually talk the student through the procedure and then check them off, deeming them competent.

Nursing faculty shortages, intense competition for both laboratory time and clinical placement sites, and the inability to ensure the clinical opportunities each student will encounter further limit the time students spend in actual patient care with expert and immediate feedback while performing procedural skills; current literature confirms this is a problem in both nursing and medical education (DeBourgh, 2011; Ironside, McNelis, & Ebright, 2014; Touchie, Humphrey-Murto, & Varpio, 2013). Both students and faculty acknowledge the importance of learning procedural skills along with the difficulties in finding opportunity to practice and demonstrate proficiency while performing these skills. All of these factors contribute to undergraduate nursing students' ability to learn and practice procedural nursing skills to an acceptable and consistent level of competence and confidence.

Stages of Motor Learning

Adult learners of any new skill start by trying to understand the task and what it demands. During the initial or cognitive phase of psychomotor skill acquisition, learners are figuring out *what* to do (Fitts & Posner, 1969; Schmidt & Lee, 2005). In the case of catheter insertion, in the cognitive phase nursing students are trying to remember the steps of the procedural checklist in order to demonstrate competence. Their movements are generally slow, inconsistent, and inefficient and require a great deal of thought and concentration (Fitts & Posner, 1969). In this phase, it is not likely that nursing students are learning the concepts of aseptic technique in order to transfer the skill to patient care, they are simply trying to figure out what is expected of them in order to correctly complete the procedure. It is likely that while the student is in the beginning, cognitive phase, the faculty is giving feedback from a perspective of more advanced skill acquisition, the autonomous phase. This difference in perspective may make it difficult for the beginner—who has not yet developed any schema or rules related to motor learning (Schmidt & Lee, 2005) and is looking for black and white, concrete answers—to assimilate and utilize the feedback most effectively.

Continued practice is required for learners to move from the cognitive phase to the associative phase and, ultimately, to the autonomous phase where the skill becomes accurate and consistent, requiring very little cognitive activity (Fitts & Posner, 1969)—and, in the case of nursing students, may free up working memory to be used for one of many other cognitive tasks required during patient care. However, the opportunity to actually perform this procedure on patients may arise infrequently while students are working in the clinical (hospital) setting, limiting the students' ability to remember and safely apply what they initially practiced in the laboratory setting and preventing them from achieving the next phase of skill acquisition.

It is important that nurse educators are open to and continually searching for effective and innovative ways to help students learn procedural skills. Nursing students must be given every opportunity to move beyond the cognitive phase and at least into the associative phase so they are prepared to begin to function effectively as graduate nurses.

Cognitive Load and Schema Theories

Nursing students are concurrently exposed to vast amounts of knowledge in the cognitive, affective, and psychomotor domains (Bloom, 1956). According to cognitive load theory, learners have a limited amount of working memory available and can therefore only access a limited amount of information at any one time (Driscoll, 2005; Sweller, van Merrienboer, & Pass, 1998). Effective learners need to develop a strategy or a mental model to help organize information in order to free up space in working memory for new information. One way to more efficiently access working memory is for the learner to develop schema.

Prior knowledge has a large impact on comprehension and memory as students learn new information and develop schema to help them access it when needed (Driscoll, 2005). When confronted with new information, learners first attempt to fit it into, or assimilate, that knowledge into something they already have experience with. In motor control and learning, both recall and recognition schema—or "the *rules* about the functioning of our bodies" (Schmidt & Lee, 2005, p. 415)—must be developed as students learn a new procedural skill. Students must practice in order to understand the relationship between the movement and the outcome in order to determine which movements will be most effective in which situation (Schmidt & Lee, 2005). It is up to nurse educators to develop learner-centered methods and pedagogies that provide opportunities for students to decrease or at least manage cognitive load while maximizing their ability to develop efficient schema.

Simulation-Based Education and Game-Based Learning

Simulation-based education (SBE)—placing students in a realistic patient care environment in order to *practice* on manikins prior to *practicing* on humans—has become an increasingly accepted and utilized pedagogy in medical and, more recently, nursing education (Decker, Sportsman, Puetz, & Billings, 2008; Garrett, MacPhee & Jackson, 2010; Jeffries, 2005; Kardong-Edgren, Willhaus, Bennett, & Hayden, 2012; Richardson & Claman, 2014). Learning with simulation varies from the use of static and partial task trainers to high fidelity manikins to standardized patients—but all forms of simulation-based education actively involve the learner.

Advantages of SBE include the ability to provide a safe environment where students can improve competency through focused and repeated practice with immediate feedback from faculty and peers (Gaba, 2004; Jeffries, 2005; Nehring & Lashley, 2009). Research into the effects of SBE on patient outcomes is difficult and remains relatively minimal (Barsuk, Cohen, Feinglass, McGaghie, & Wayne, 2009; Barsuk, McGaghie, Cohen, O'Leary, & Wayne, 2009; Cook et al., 2012; McGaghie, Issenberg, Cohen, Barsuk, & Wayne, 2011a), however research has repeatedly demonstrated positive effects of SBE on learning in healthcare, including learning procedural skills (Bland, Topping, & Wood, 2011; Cook et al., 2012; Decker et al., 2008; Domuracki, Moule, Owen, Kostandoff, & Plummer, 2009; Harder, 2010; Kirkman, 2013; McGaghie, Issenberg, Petrusa, & Scalese, 2006, 2010; Oermann, Kardong-Edgren, & Odom-Maryon, 2011; Onda, 2012).

Many and varying definitions of simulation and gaming exist in the literature as well as definitions of the differences between the two, with some authors making a very clear distinction. For the purpose of this study, game-based learning (GBL) was considered one form of simulation-based education, in which students are immersed in a safe environment with plenty of opportunity for repeated practice and immediate feedback (Bauman, 2013; Crookall, 2010; Educause Games and Learning Constituent Group, 2014). The discussion will focus on the addition of game-based learning elements (i.e., competition, rules, motivation, a clear and attainable goal, trial and error, immersion, and engagement) and how they contribute to experiential learning using technology that most students are comfortable with (Bauman, 2013; Gee, 2007; Prensky, 2001)—technology that may be useful for nursing students in practicing procedural skills. Though it can be argued whether or not the system fits the definition of a game, the developers intentionally incorporated some game elements into the system and it will subsequently be referred to as a *virtual reality game*.

Deliberate Practice

Consisting of well-defined objectives that guide motivated learners to improve their skills through focused, repetitive practice with immediate feedback, error correction, and gradually increasing difficulty (Ericsson, Krampe, & Tesch-Romer, 1993), deliberate practice is emerging as another form of simulation-based education in medicine and, more slowly but surely, nursing education. McGaghie, Issenberg, Cohen, Barsuk, and Wayne (2011b) have shown that simulation that incorporates deliberate practice is superior to traditional education in achieving acquisition of clinical skills including advanced cardiac life support, cardiac auscultation, and central venous catheter insertion. Students cannot be expected to successfully master skills if they are not given the opportunity and are not expected to practice deliberately and repetitively. Students need to spend focused time and energy practicing correctly in order to reach a level of proficiency or *muscle memory* and then continue to practice regularly to maintain that level. One of the purposes of the development of the VR game tested in this study is to provide students the means and method to practice urinary catheter insertion on their own repetitively, with immediate feedback on performance that does not require the time and cost associated with a trained observer. McGaghie, et al.(2006) determined that there is a strong association between hours of practice and learning outcomes approximating a dose-response relationship. Using technology and GBL strategies to provide students with a method to practice that is engaging and motivating may help them move from the cognitive to the associative phase of motor learning.

Virtual Reality and Haptics

The use of virtual reality (VR) in healthcare is defined as “a digital space in which a user’s movements are *tracked* and his or her surroundings *rendered*, or digitally composed and displayed to the senses, in accordance with those movements…allowing a much greater level of interactivity than traditional media” (Fox, Arena, & Bailenson, 2009, p. 95-96). The ultimate goal of VR in healthcare is “to present virtual objects or complete scenes to all human senses in a way identical to their natural counterpart” (Szekely & Satava, 1999, p. 1305). This VR game differs significantly from Internet screen-based VR simulations such as Second Life™ in which the user interacts through an avatar. The wearer of the headgear and haptics (interactive gloves) used in this VR game is *in the room* with the patient, virtually inserting a urinary catheter using his or her own hands. Haptics is the science of applying touch or tactile sensation; in VR, haptics is used as an output tool to help integrate visual technology and reproduce an interactive virtual environment (Pensieri & Pennacchini, 2014). Haptic enhancement to the virtual reality headgear used in this study allows users to virtually *touch* and *pick up* the simulated objects with which they interact.

Picture 1.1 Student in headgear and haptics

The unique VR game tested in this study was made possible with the release of the Oculus Rift development kit in 2014 (Albanesius, 2014; Parkin, 2014). Oculus Rift is an affordable virtual reality headset that its developer, 21-year-old Palmer Luckey, designed using cheap smartphone components “combined to stunning effect, rendering bright, crisp worlds much more compelling than the blocky graphics often seen through earlier virtual reality headsets” (Parkin, 2014, p. 52).

The Oculus Rift headset provides two separate images, one for each eye, that together give the wearer a 100 degree field of stereoscopic vision at high resolution, filling the wearer’s peripheral vision and thereby providing a sense of total immersion in the environment (Firth, 2013)—in this case, the patient’s hospital room. A camera tracks an optical sensor that indicates the user’s position in the room and head movements are relayed to a computer that determines what the user will see in the headset (Fox et al., 2009).

Picture 1.2 Student in headgear and haptics inserting catheter virtually

In addition to filling the wearer’s peripheral vision, the Oculus Rift’s custom 360 degree tracking technology allows the wearer to look around the virtual world just like real-life, tracking even subtle head movement in real time thereby reducing the simulator sickness effects of older—and much more expensive—VR technology (Parkin, 2014). Oculus Rift, soon to be released to the general public, has created widespread optimism among not only gamers, but also many others regarding this immersive technology and the potential it holds for much more than gameplay (Albanesius, 2014).

Project Background

The Principle Investigators for this project recognized the potential of using Oculus Rift technology to help students practice procedural nursing skills. The VR game developed by the research team combines Oculus Rift with a custom haptic system and game-based learning elements to produce a vehicle for learning that is familiar to current students, many of whom grew up with the internet and playing video games (Gee, 2007; Prensky, 2001). This VR game could significantly impact how nursing and medical training is carried out in both higher education and clinical institutions.

The northwest university that developed the VR game discussed in this study is home to a simulation center accredited by the Society for Simulation in Healthcare (SSH) in the category of teaching and education (SSH, 2015). This center is one of only a handful of accredited centers in the world that is not affiliated with a major medical institution (SSH, 2015). Several nursing faculty in the School of Nursing have demonstrated expertise in teaching with simulation by earning designation as Certified Healthcare Simulation Educators (CHSE). Numerous faculty have published peer-reviewed articles and given presentations on a variety of simulation topics and technology-based learning issues. These topics range from using simulation to determine responses to medication errors (Breitkreuz, Dougal, & Wright, 2015), to helping new graduates deal with incivility issues in the workplace (Clark, Ahten, & Macy, 2014), to investigating the use of expert modeling (Kardong-Edgren, et al., 2015), to involvement in the National Council of State Boards of Nursing study (Kardong-Edgren et al., 2012), to the use of immersive VR (Connor, 2012), educational technology (Connor & Walker, 2013), and virtual multiple patient simulation (Josephsen & Butt, 2014). Developing and using simulation, including game-based learning and the use of virtual reality for teaching and learning, are all topics of ongoing practice and research in this School of Nursing.

This study grew from a collaborative project between faculty in the computer science department and the School of Nursing. Development of this VR game is the first phase of a project with a long-term goal to "create a set of digital tools and methodologies which will allow (the university) to deliver high quality nursing and medical simulations at distance" (Kardong-Edgren & Ellertson, 2013). Nursing faculty served as content experts related to the nursing procedure as well as inclusion of GBL elements, working alongside the development team as they combined innovative technology to produce a tool that we hypothesize will be valuable for learning. The team successfully produced a one-of-a-kind, fully immersive VR game offering students a new opportunity for practicing urinary catheter insertion repetitively and with immediate feedback on performance. This study is the first test of the game's usability and effectiveness.

Recent literature specific to nursing education includes reference to computer-based virtual reality (Jensen & McNally Forsyth, 2012), virtual worlds (Green, Wyllie, & Jackson, 2014), virtual clinical simulation (Foronda, Godsall, & Trybulski, 2013), the use of avatars for active and group learning in nursing education (Ahern & Wink, 2010; Sweigart, Burden, Hodson, Carlton, & Fillwalk, 2014) and computer-based simulation for skills training (Johannesson, Silen, Kvist, & Hult, 2013). Combining VR headgear, haptics and game-based learning elements *for educational purposes* is a new idea in nursing education, largely because development of the technology is currently in progress. No reference to this type of immersive learning experience used to practice procedural skills was found in the literature.

Nurse educators need to investigate new learning technology and strategies in order to truly transform nursing education with the goal of producing graduate nurses that can demonstrate competence and provide safe patient care when performing procedural skills. This VR system provides a learner-centered environment that focuses on individual learner needs and provides consistent feedback, decreasing cognitive load related to faculty preferences and biases in teaching the procedure and providing a method for repeated and deliberate practice by students. This study is important because it seeks to determine the usability and effect of new and innovative VR technology when used to promote procedural skill development in undergraduate nursing students. Maintaining aseptic technique during insertion of a urinary catheter is an important foundational nursing skill and will be used as an exemplar.

This study will contribute to filling the gap in the research regarding the use of three dimensional virtual reality with haptics and game-based learning elements to fully immerse and engage students in the learning experience. If this technology is perceived by students as a useful way to practice procedural skills and can demonstrate promotion of learning and retention, it may be one more tool that nurse educators have available to better prepare undergraduate nursing students to provide safe, high quality patient care.

In addition to providing the opportunity for students to practice a complete library of individual procedural skills, the team foresees potential for multiplayer games involving interdisciplinary players that could meet online and practice virtually running a cardiopulmonary resuscitation (Code Blue) together, for example. Finding educational methodologies with the greatest impact in promoting competence and retention of procedural skills is important for patient safety and health promotion.

Purpose Statement

The purpose of this study was to explore the use of immersive virtual reality and haptic technology combined with game-based learning elements to provide an innovative method for undergraduate nursing students to practice a procedural nursing skill, eliciting user experience and reactions to the technology for learning. This is the first iteration of this VR game and though this study is primarily a usability study—a preliminary validation of the system itself—the study also provided an initial analysis of the effect of this technology on undergraduate nursing students' ability to demonstrate competence in maintaining aseptic technique two weeks after the practice session, using urinary catheter insertion as exemplar.

Problem Statement

Undergraduate nursing students must be prepared to competently and confidently perform procedural skills during patient care, including maintaining strict aseptic technique when needed. Students need time and opportunity to practice procedural skills in order to become competent. Lack of time in the practice lab and/or lack of clinical placement experience including expert feedback on performance may limit opportunities for nursing students to master procedural skills; this lack of focused, repetitive practice including immediate feedback may leave students less than optimally prepared when called upon to perform procedures in clinical practice. Nurse educators are challenged to seek out and implement innovative strategies that provide opportunities for students to practice procedural skills while ensuring patient safety. Combining virtual reality headgear and haptics with game elements may be a unique and valuable method to promote deliberate practice of procedural skills in undergraduate nursing students, however no research into its usability for this purpose exists.

Research Questions

The research questions to be addressed in this study include:

1. How do subjects rate the usability of a game-based virtual reality system for practicing urinary catheter insertion?
2. What is the user experience related to enjoyment, engagement, comfort, likelihood to practice and preference compared to traditional practice on a task trainer?
3. Is there any difference in time spent practicing and/or number of procedures completed in sixty minutes when comparing subjects that practiced with the VR game to those that practiced on a task trainer?
4. Is there any difference in ability to demonstrate aseptic technique during urinary catheter insertion two weeks after completing practice sessions when comparing subjects that practiced with the VR game to those that practiced on a task trainer?

Theoretical Foundation

Literature regarding the use of games for educational purposes crosses several diverse disciplines including media literacy, psychology, computer science, and education (Dipietro, Ferdig, Boyer, & Black, 2007). The literature also includes a wide variety of terms and definitions of gaming technology and its uses. Experiential learning theory (Kolb, 1984) will serve as a broad theoretical base for this study, supported by deliberate practice theory (Ericsson et al., 1993) and cognitive load theory (Paas & van Merrienboer, 1994). The designed experiences framework (Squire, 2006) will provide the basis for understanding related more specifically to game-based learning. See Chapter 2 for in-depth discussion of the theoretical model.

Nature of the Study

This research study is primarily a mixed methods survey of the usability of this virtual reality game as a tool for practicing procedural skills, with urinary catheter insertion as exemplar. In addition to observation and post-intervention surveys to explore the usability of the VR system, this research study utilized a small scale quasi-experimental design to determine the effect of the technology on participants' ability to demonstrate proper aseptic technique two weeks after practicing, either with the VR game or on a task trainer with faculty feedback. The use of immersive gaming technology will serve as the independent variable while the dependent variable for the study will be participants' ability to demonstrate competence maintaining aseptic technique while inserting a urinary catheter. Digital video recordings of the student participants while playing the game and post-intervention interviews will be used to elicit participants' reactions to the usability and perceived usefulness of the immersive game as a learning tool.

A small sample was intentionally used for this study, because it is primarily a usability study of the technology (Nielsen, 2012). The study sample consisted of twenty undergraduate nursing students purposively selected from two clinical courses consisting of approximately 120 students. Informed consent was obtained from all study participants after university Institutional Review Board approval was applied for and secured. Participants completed a demographic survey including age, gender, ethnicity, experience with gaming, and comfort with technology and learning with simulation. All participants had previously demonstrated competence in catheter insertion on a task trainer using a standard criterion-based checklist at least once during their six semesters in the eight semester nursing curriculum; therefore, no further pre-test was required of students. However, experience as well as small-scale research (Gonzalez & Sole, 2014; Mulcock & Kardong-Edgren, 2014) suggests that even though students had previously "checked off" on this skill, at least some of these students would most likely not be able to demonstrate competence.

Participants were divided into control and intervention groups. All study participants were given one hour of practice time and were encouraged to use as much or as little time as they desired. The ten participants in the intervention group individually received instructions about how to play the game followed by practicing catheter insertion using the game. The control group was given the opportunity to practice on a task trainer in the lab as students in this nursing program normally do, working with a partner and provided immediate feedback from faculty. Time-on-task was recorded for each student, both control and intervention groups. Immediately upon completion of their practice time, each participant in the intervention group completed two surveys, one regarding the usability of the system itself while the other surveyed user-experience and reaction to the game for practicing catheter insertion. Approximately two weeks after completion of the practice session, all study participants returned to the simulation center to conclude the study with a posttest consisting of skill demonstration on a task trainer using the criterion-based checklist (see Appendix A).

All participants were digitally recorded during practice time as well as follow-up catheter insertion demonstration. These recordings were reviewed for time spent practicing (total minutes out of sixty) and number of procedure completions. Video recordings of the screen shots of the intervention group included a review of how participants navigated the technology as well as any qualitative responses. The follow-up demonstrations were scored for each participant's ability to successfully maintain aseptic technique by a trained, but blinded, reviewer using the criterion checklist utilized by the School of Nursing. Another blinded reviewer scored five of the follow-up demonstrations chosen randomly to check for inter-rater agreement.

Descriptive statistics and qualitative reactions are reported in Chapter 4; data from skills demonstrations were analyzed for differences. See Chapter 3 for detailed information regarding plan for data collection and data analysis.

Definition of Terms

Aseptic technique: any health care procedure in which added precautions, such as use of sterile gloves and instruments, are used to prevent contamination of a person, object, or area by microorganisms.

Clinical judgment: The art of making a series of decisions to determine whether to take action based on various types of knowledge. The individual recognizes changes and salient aspects in a clinical situation, interprets their meaning, responds appropriately, and reflects on the effectiveness of the intervention. Clinical judgment is influenced by the individual's previous experiences, problem-solving, critical-thinking, and clinical reasoning abilities (Meakim et al., 2013).

Clinical placement or clinical practice: Any situation in which nursing students are actually assessing patients and providing appropriate care based on what they have learned in the classroom—putting into practice at the bedside what they have learned in class. Historically, clinical practice occurred almost exclusively in a healthcare facility with living patients; with the development of simulation equipment and pedagogies, clinical practice is now likely to include patient care in simulation scenarios as well (Ironside et al., 2014; Tanner, 2006a).

Competence: For the purpose of this study, competence is defined as having the ability to apply necessary knowledge and skills to patient care (Decker et al., 2008), most often assessed by a criterion-based procedural checklist in nursing education.

Engagement: Related to learning with games, in this study engagement is defined as "being concerned with all the qualities of an experience that really pull people in…including a sense of authenticity of and identification with the environment…, a sense of immersion, and creating an experience of flow" (Whitton, 2011, p. 598).

Feedback: Information given or dialogue between participants, facilitator, simulator, or peer with the intention of improving the understanding of concepts or aspects of performance (Meakim et al., 2013).

Flow: "The state in which people are so involved in an activity that nothing else seems to matter; the experience itself is so enjoyable that people will do it even at great cost, for the sheer sake of doing it" (Csikszentmihalyi, 1990, p. 4).

Game-based learning: Part of the dilemma in doing any kind of educational research related to "games" is the plethora of definitions assigned to the topic. For the purpose of this study, game-based learning will be defined as any activity that is (1) interactive, (2) based on a set of agreed-upon rules and constraints, (3) directed toward a clear goal that often includes challenge, and (4) includes on-going feedback that enables players to monitor their progress (Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013).

Haptic: Based on the sense of touch, haptics in VR are used as an output tool to help integrate visual technology and reproduce an interactive virtual environment (Pensieri & Pennacchini, 2014). Haptic enhancement to the VR headgear used in this study allows users to virtually *touch* and *hold* the simulated objects with which they interact.

Nosocomial infection: Infection acquired or occurring in a hospital.

Procedural skill: Combining appropriate knowledge and psychomotor skills in order to correctly and safely carry out necessary patient care, for example, placing a urinary catheter, assisting with chest tube placement, or giving medications per a nasogastric tube.

Psychomotor skill: "The ability to carry out physical movements efficiently and effectively, with speed and accuracy. Psychomotor skill is more than the ability to perform: it includes the ability to perform proficiently, smoothly, and consistently under varying conditions and within appropriate time limits" (Meakim et al., 2013, p. S8).

Schema: A way to store and organize knowledge by chunking multiple elements of information into a single element, storing knowledge in long-term memory until it is needed (Paas & Sweller, 2012).

Task trainer: A form of simulation that involves a static manikin or partial manikin, usually a specific anatomic body part, used to learn, practice, and gain competency in simple to complex techniques, skills, and procedures (Decker et al., 2008).

Usability: Defined as a quality attribute, usability in this study refers to ease of system use, including learnability, efficiency, memorability, number of errors involved in navigating the system, and degree of satisfaction for the learner (Nielsen, 2012).

Virtual Reality: While there are many and varied definitions and interpretations of the term, for the purpose of this study, virtual reality refers to completely immersive three-dimensional Oculus Rift headgear (Albanesius, 2014) plus wearable haptic technology that allows students to complete urinary catheter insertion virtually—nursing students are inserting a virtual catheter into a virtual patient using their own hands.

Assumptions of the Study

This study includes the following assumptions:

- Learning can be measured by competence; competence can be determined by observation.
- Competence demonstrated on a task trainer will transfer to patient care.
- Students in the study will complete the task to the best of their ability and provide honest responses to survey questions.

Limitations of the Study

Several limitations to this study have been identified:

- With the goal of initially validating usability of this technology, a small sample from a representative group of undergraduate students was used.
- Willingness to participate in the study may have been influenced by students' initial comfort level with technology and gaming.
- Data was collected over a short period of time, in one northwest university baccalaureate nursing program.
- Due to the game mechanics, study participants were limited to those students that are right-handed or ambidextrous; volunteers that were left-handed-only were automatically placed in the control group.

In summary, as an initial validation of this innovative technology, and based on usability principles (Nielsen, 2012), this study was intentionally limited in size. After initial usability ratings of the VR technology have been obtained and improvements made to the system as appropriate, the study should be expanded to include other settings with more participants over an extended time period in order to obtain more powerful data that may then be more generalizable.

Significance of the Study

Undergraduate nursing students are expected to function effectively in a changing and challenging healthcare system where nurses' knowledge, understanding, and clinical judgment combine to promote best patient outcomes. The practice of nursing requires the understanding of pathophysiology and disease processes in order to promote health, alleviate suffering, and protect patients from further harm. Nursing practice also requires demonstration of technical procedural skills necessary to safely provide appropriate medical interventions. Nurse educators have a responsibility not only to their students, but a greater responsibility to society as a whole, to prepare graduate nurses that can step into a complex healthcare system and deliver safe, high-quality care. Employers, the government, and the public are asking educators to do a better job of preparing students, regardless of the many challenges faculty may face (Benner, Sutphen, Leonard, & Day, 2010; Institute of Medicine, 2011; Jeffries, 2005).

The National League for Nursing has repeatedly issued position statements stressing the need for evidence-based nursing education, including the use of innovative technology (NLN, 2003, 2008, 2015). The NLN charged nurse educators to move beyond traditional education practices and ensure that curriculum and teaching practices are innovative yet evidence-based. As new forms of educational technology become increasingly available, it is important to consider their usefulness as innovative tools for learning procedural nursing skills. The results of this study may benefit nurse educators by supplying evidence to support curricular and pedagogical changes, aiding in the transformation of nursing education. These changes will help prepare graduate nurses that are better qualified to provide high quality, safe patient care in a complex and rapidly-changing healthcare system. There is a need for research into best practices in promoting learning and retention of procedural skills in nursing education. Information gathered in this small study may help us to address the bigger question: How do we more effectively promote learning and retention of procedural nursing skills in undergraduate nursing students?

CHAPTER TWO: REVIEW OF LITERATURE

Undergraduate nursing students are exposed to an overwhelming and ever-increasing amount of content knowledge, long referred to as the "additive curriculum" (Diekelmann, 2002, p. 469). This presents a dilemma for nursing faculty as well as students in regards to the cognitive, psychomotor, and affective learning domains (Bloom, 1956) as they apply to nursing education. Students are faced with the cognitive task of learning pathophysiology, pharmacology, anatomy and physiology, therapeutic communication, care planning, disease prevention, and health promotion; they must also learn the psychomotor tasks that include procedural skills and be prepared to perform them safely and competently. Students must become proficient in these areas while also attending to their patients' emotional needs. Nurse educators are challenged with finding ways to promote learning in order to develop graduate nurses that are able to "think like a nurse," acting independently to provide safe, high-quality patient care while effectively communicating with patients.

Though it cannot be separated from the other learning domains, the focus of this study is primarily on the psychomotor domain. Providing excellent nursing care involves much more than carrying out procedural tasks, however competence in performing procedural skills is an important foundation for nursing practice and one that student nurses must focus on as they begin to understand their role and develop confidence in their ability to function as a professional nurse.

The literature review will discuss the current research related to game-based learning and simulation-based education and their relationship to nursing education. The review will also provide an overview of the literature used to form the theoretical framework used in this study. Experiential learning (Kolb, 1984) will serve as a broad foundation, supported by deliberate practice (Ericsson et al., 1993) and cognitive load theories (Paas & van Merrienboer, 1994); these learning theories converge and culminate in the learner actively participating in a designed experience (Squire, 2006). In this case, the designed experience consists of an immersive learning experience created by combining virtual reality headgear and haptics with game-based learning elements to give students the opportunity to virtually practice urinary catheter insertion.

Urinary Catheter Insertion as Exemplar for This Study

Demonstration of aseptic technique is a vital component of several procedural skills that nursing students must master. In order to protect patients from the risk and complications of catheter-associated urinary tract infections (CAUTI), for example, strict aseptic technique must be maintained throughout the procedure of urinary catheter insertion. There are several steps involved in the procedure and several places where aseptic technique may be broken, leaving the patient at-risk for infection. Urinary tract infections account for up to 30% of nosocomial infections; potential complications of CAUTI include increased morbidity and mortality, lengthened hospital stays, and increased cost to the patient and healthcare facility (Centers for Disease Control and Prevention, 2010; Agency for Healthcare Research and Quality (AHRQ), 2013).

According to the AHRQ (2013, opening paragraph), “At any given time, healthcare-associated infections (HAI) affect 1 out of every 20 hospital patients” with

CAUTIs among the most common HAIs in the United States; the Joint Commission (2011) attributes 80% of HAIs to an indwelling urethral catheter. The Centers for Medicare and Medicaid Services (CMS) consider CAUTIs a reasonably preventable complication of hospitalization, and therefore no additional payment is provided to hospitals for CAUTI treatment-related costs (CMS, 2014).

Adherence to aseptic catheter insertion as a general infection control principle is one factor included in a widely used “bundle” checklist for prevention of CAUTIs (Newman, 2011). The procedure of inserting urinary catheters is limited to professionals who are trained and competent in maintaining aseptic technique throughout the entire procedure. With hospital/provider reimbursement tied to HAI, but more importantly, with patient safety at stake, it is imperative that nursing students demonstrate consistent and proper maintenance of aseptic technique while inserting a urinary catheter.

A recent study found what many clinical nursing faculty know to be true—students generally self-report confidence in performing urinary catheterization; video recordings in this study, however, showed that the majority of students demonstrated at least one break, and in some instances, several breaks in aseptic technique during the procedure, even after documented skill competence (Gonzalez & Sole, 2014). Another small study (Mulcock & Kardong-Edgren, 2014) supported this finding when one of 14 students that had been deemed competent via a criterion-based checklist was able to complete the entire procedure without at least one break in aseptic technique approximately six months later. Anecdotal conversations with clinical faculty who work with student nurses in the acute healthcare settings as well as preceptors who mentor and orient newly graduated nursing students will likely support these findings.

There is ongoing discussion in the literature about the theory to practice gap—or, more accurately perhaps, the education to practice gap—and the role of academia in better preparing graduate nurses for practice (Berkow, Virkstis, Stewart, & Conway, 2008; Burns & Poster, 2008; del Bueno, 2005; Onda, 2012; Theisen & Sandau, 2013; Thomas, Bertram, & Allen, 2012). Utilization of innovative technology for practicing procedural skills may be beneficial in preparing graduate nurses for the complex environment they will enter upon graduation; implementation and evaluation of novel technology and related pedagogies by nursing faculty is not only necessary, but critical in nursing education.

The purpose of this study was to explore the usability and user experience of a system combining virtual reality and haptics with game-based learning elements, intended for use by nursing students to practice maintaining aseptic technique while virtually inserting a urinary catheter. Students were observed while practicing with the game and then completed a System Usability Survey (Brooke, 1996) including an adjective rating scale (Bangor, Kortum, & Miller, 2009) as well as a user reaction survey. The study also investigated any effect the game may have on procedural skill development and short-term retention of the students' ability to demonstrate aseptic technique two weeks post-practice session. Urinary catheter insertion served as the exemplar for demonstration of aseptic technique in this study.

Nursing Education

For many years, nursing education in the United States consisted of almost exclusively hospital-based diploma programs. These were service-driven programs, often religious-based, and though they included some classroom instruction, in truth, the young women who entered these programs fulfilled a need for unskilled and inexpensive labor; in many cases, their education was their salary (Bevis & Watson, 1989). Nursing education followed an apprenticeship model, with students caring for patients in the hospital under the supervision of more senior nurses. Nursing continues to struggle to identify itself as a profession rather than a vocation, related at least in part to this history. Many people have little understanding of the role of the professional nurse with their exposure to nurses limited to either personal experience or what they see on television. Students entering nursing school are likely to hear about "thinking like a nurse" but often do not have their eyes opened to what that actually encompasses until they have spent time working with patients and their nurses.

Numerous and substantial changes in healthcare have, in turn, required substantial changes in the role and preparation of the registered nurse, however clinical education of nurses continues to utilize a somewhat similar apprenticeship model (Ironside et al., 2014). Nursing students attend classes on university campuses (or, increasingly, on-line) to learn the information needed in order to care for patients in a clinical setting; this includes spending time in a laboratory or learning center practicing procedural skills. As a practice-based profession, nursing students need to assimilate the information presented didactically in the classroom and learn how to apply it in the clinical context. It would seem logical that in order to learn to apply this information, students must spend time in clinical practice, providing patient care.

Individual clinical nursing faculty is traditionally assigned a clinical placement site and a group of 8-10 nursing students overseen by faculty in the facility for a pre-determined number of hours (actual requirements may vary depending on State Board of Nursing and institution). It is not uncommon for a clinical group to be assigned to several different units within the hospital in order to accommodate the group; rather than being involved directly in patient care, students may end up observing in areas where their inexperience prevents them from participating in patient care (i.e., the surgical suite, emergency department, or interventional medicine). While these are interesting opportunities for students, they do not engage the student in active learning. Each day individual student placements depend on patient census and acuity and the number of nursing staff available to work with students. Also, traditionally, some staff nurses are more willing to work with a student on any given day than others, another factor that influences students' learning experience. Learning opportunities depend on what is happening with patients during the limited time students are on the unit; opportunities may, therefore, be very different from one unit to the next but also from one student to the next, and may not give students the chance to put into practice what they are learning in class. Obviously, when faculty is responsible for a group of students that is scattered throughout the hospital, the amount of quality time faculty have to spend with each student is limited; if the opportunity arises to perform a procedural skill, the faculty may or may not be available to oversee and provide immediate feedback on performance (Ironside & McNelis, 2010; Tanner, 2006a). Despite the associated problems—and the awareness of the limitations of this approach—clinical education in nursing has changed very little over time (Ironside et al., 2014; Tagliareni, 2009; Tanner, 2006b).

The traditional Halstedian apprentice model of “see one, do one, teach one” (Halsted, 1904) historically subscribed to in medicine and nursing education is outdated and not based on best practice. With higher patient acuity, shorter hospital stays and an ever-growing emphasis on patient safety, both medical and nursing students have fewer opportunities to *practice* procedures on patients (Founds, Zewe, & Scheuer, 2011; Rodriguez-Paz et al., 2009). It is apparent that current methods of learning procedural skills often do not result in competence or retention of skill demonstration in practice (DeBourgh, 2011; Gonzalez & Sole, 2014; Oermann et al., 2011; Rodriguez-Paz et al., 2009) and are not necessarily evidence-based (Allan & Smith, 2010; Robinson & Dearmon, 2013). Procedural or psychomotor skill learning in nursing and medical education typically relies heavily on memorization of steps from a criterion-based checklist that students use to demonstrate initial competency in the laboratory; students are then declared ready to perform the procedure on patients (Rodriguez-Paz et al., 2009). However, because students may not have the opportunity to practice this procedure after initial check-off, they are likely to remain in the cognitive phase of motor learning and when they are called upon to perform the procedure with patients, students may struggle to remember—and more importantly, perform safely—what they initially learned in the lab.

Traditional clinical education is also very time- as well as resource-intensive and there is very little evidence regarding associated learning outcomes (Ironside et al., 2014). Community partners hiring new graduate nurses often lament these nurses’ lack of preparation, citing procedural skills as one of many areas they consider less than adequate (Berkow et al., 2008; del Bueno, 2005) and suggesting students may need greater exposure to basic nursing skills, including catheter insertion (Thomas et al., 2012).

Ten years ago, and approximately twenty years after the National League for Nursing (NLN) called for a "Curriculum Revolution" in the 1980s, the NLN (2003) developed and distributed a position statement, *Innovation in Nursing Education: A Call to Reform,* demanding nursing faculty "challenge their long-held traditions and design evidence-based curricula that are flexible, responsive to students' needs, collaborative, and integrate current technology" requiring "bold new thinking and action" (p. 1). In 2011, with recent passage of the Affordable Care Act, the Institute of Medicine (IOM) published its report, *The Future of Nursing: Leading Change, Advancing Health*, prompting nurse educators and administrators to, once again, take a serious look at the way we educate future nurses. Key Message #2 of the IOM report (Institute of Medicine, 2011, p. 163): "Nurses should achieve higher levels of education and training through an improved education system that promotes seamless academic progression." The committee realized major changes in the health care system would also require profound changes in the way we educate the nurses of the future, stating "…nursing education needs to be transformed in a number of ways to prepare nursing graduates to work collaboratively and effectively with other health professionals in a complex and evolving health care system in a variety of settings" (Institute of Medicine, 2011, p. 164).

Though nursing educators continue to discuss the need for change, and though we have numerous advances in technology available to aid in this "revolution," many continue to teach the way they were taught (Diekelmann, 2002). Simulation-based education and game based learning present innovative methods for learning procedural nursing skills.

Simulation-Based Education

Simulation has been used for many years in other industries, particularly aviation and the military. Simulation based-education (SBE) in nursing education dates back to the early 1900s when students were introduced to Mrs. Chase, the first life-sized manikin used for various procedures (Nehring & Lashley, 2009). The National League for Nursing (NLN, 2003) endorsed the use of simulation in order to prepare nursing students for the complex clinical environment. Simulation-based education encompasses a wide variety of definitions and learning experiences: simple task trainers or partial manikins on which students can practice procedural skills, high-fidelity manikins that require students to respond to a changing patient care situation that can be manipulated and guided by faculty as the voice of the patient, and experiences with standardized patients in which students interact with a living person trained to act as a patient with particular medical or psychosocial needs. SBE may also include role-playing and games that are used to immerse the student in an active learning experience.

An integrative review of simulation in medical education (Issenberg, McGaghie, Petrusa, Gordon, & Scalese, 2005) discusses ten features of high-fidelity simulation that lead to effective learning and are also highly relevant in this discussion as it applies to game-based learning:

- Feedback provided during the learning experience.

- Repetitive practice.
- Integration into overall curriculum.
- Increasing levels of difficulty.
- Adaptability to multiple learning strategies.
- Opportunity for clinical variation.
- Controllable environment where learners can make and detect mistakes without consequences.
- Students' active participation in learning with responsibility for own learning.
- Clearly identified outcomes and benchmarks.
- Strong face validity of the simulator.

The literature is in agreement that integrating SBE into nursing education curriculum provides active learning in a safe, realistic, non-threatening environment where students are allowed to make mistakes and learn from them, knowing they will not cause harm to patients (Decker et al., 2008; Foronda, Liu, & Bauman, 2013; Gaba, 2004; Jeffries, 2005). For these reasons, simulation has been used increasingly to augment clinical learning (Foronda, Godsall, & Trybulski, 2013; Harder, 2010; Hayden, Smiley, Alexander, Kardong-Edgren, & Jeffries, 2014; Kneebone, 2005; Tanner, 2006a). With advancements in high-fidelity simulation, educators can expose learners more uniformly to clinical situations that they may not encounter during actual in-hospital clinical rotations; this includes the opportunity to combine experiences from all three learning domains in order to develop clinical judgment (Berragan, 2011; Cook et al., 2012; Foronda & Bauman, 2014; Harder, 2010; Jeffries, 2005). For instance, students can practice individual steps of psychomotor skills on a task trainer before practicing those same skills in-context during a scenario that requires them to also apply cognitive and affective learning domains as they provide patient care. Simulation-based education done well is highly experiential; simulation places learners in a designed experience with the goal of applying and analyzing what they have learned in class in order to experiment and construct knowledge in the simulation lab—knowledge that can then be transferred to patient care. Simulation-based education can help close the theory to practice gap by engaging students in their own learning and construction of knowledge, thereby helping students create or strengthen a link between theory and practice. Students are provided the opportunity to test out their knowledge in-context and respond appropriately. Arguably, this link will promote better retention of knowledge as well as consistency and proficiency in demonstration of psychomotor skills.

Nursing education has borrowed from SBE research in medicine over the years, just as medicine initially learned about using simulation from more established professions like aviation and the military. Important practice points include the need to integrate simulation into the curriculum carefully and intentionally (rather than using it as an add-on), always keeping the desired outcomes in mind (Mottola, Devine, Chung, Sullivan, & Issenberg, 2013). The ability to transfer knowledge and skills practiced in simulation to the traditional clinical setting is important as the ultimate goal of SBE. Transfer of learning has been minimally researched in the discipline of nursing. However, there is significant evidence supporting transfer of learning to the clinical setting available in medicine, most typically related to surgical procedures (Domuraki et al., 2009; Lucas et al., 2008; McGaghie et al., 2011a; Stefanidis, Acker, & Henniford, 2008).

Recent small studies specific to nursing students (Kirkman, 2013; Rutherford-Hemming, 2012) support medical education-based research, demonstrating a significant positive effect on participants' ability to transfer knowledge and skills to the traditional clinical setting. One larger, descriptive, longitudinal study (Sportsman, Schumacker, & Hamilton, 2011) found no significant difference in mean scores related to psychomotor skill performance of students who had traditional clinical hours replaced with simulation hours. This study suggested that students were able to learn skills in simulation that are normally learned during traditional clinical practice.

Research concerning simulation-based education in nursing initially focused on self-reported student satisfaction and confidence levels (Alfes, 2011; Fountain & Alfred, 2009; Hope, Garside, & Prescott, 2011; Smith & Roehrs, 2009). While this is interesting and useful information, it does not address the ability of SBE to translate to learning outcomes. Questions have been raised about the inconsistency and lack of rigor in study design utilized in simulation research (Cant & Cooper, 2009; Gunberg Ross, 2012; Harder, 2010; Issenberg et al., 2005) and the inability of research to keep up with the technology (Bland et al., 2011; Foronda, Liu, & Bauman, 2013). As educators, it is important to provide the basis for the tools and pedagogies we choose to use. Technology may be useful as a teaching/learning tool, however using it simply because we can is not enough.

Simulation-based education has been accepted and implemented in nursing education as an adjunctive form of learning; however, the literature is clear that more research—including research with more rigorous research design—is necessary to provide the evidence needed to fully support the integration of simulation into nursing curriculum. Empirical research is also needed to justify the cost of high-fidelity simulators and the faculty training that is required to utilize simulators to their potential. Rather than merely accepting simulation as the latest in nursing education, further research as well as development of theory regarding simulation as a teaching modality is required (Schiavenato, 2009). Research into best practice related to substituting traditional clinical practice with simulation is important as the National Council of State Boards of Nursing (NCSBN) attempts to determine just how many simulation hours may be substituted for traditional clinical hours during a student's nursing education. One of the benefits of well-run SBE is that time in the simulation lab is typically very focused on specific learning outcomes, while hours in clinical practice settings often include a large amount of task-based activity (Ironside et al., 2014) as well as "education by random opportunity" (LeFlore, Anderson, Michael, Engle, & Anderson, 2007). Currently, there are very limited state by state guidelines regarding the percentage of clinical hours that may be spent in simulation; there are no current guidelines about how actual hours in the simulation lab compare to hours in clinical practice—how these compare for learning has yet to be determined.

Recently, a landmark multi-site, randomized and controlled longitudinal study set out to address these questions. The study, supported by the NCSBN, followed 666 students from ten different sites across the United States through their nursing education and six months into their first year of employment. The study compared learning outcomes of students who had varying amounts of simulation substituted for traditional clinical practice hours (Hayden et al., 2014). Technical skills were included in the study as a category of measurement. Power analysis results, sample size determination, and reliability statistics of several data collection instruments utilized at various points in the study were all reported. Results of this multiple phase study demonstrated no significant difference in knowledge, clinical competency, or overall readiness for practice in students who had 10% simulation (a "business-as-usual," controlled comparison group) versus students that had 25% or 50% simulation substituted for traditional clinical practice time (Hayden et al., 2014). It is important to note that in order to generalize these results, conditions similar to those of the study are necessary: "These conditions include faculty members who are formally trained in simulation pedagogy, an adequate number of faculty members to support the student learners, subject matter experts who conduct theory-based debriefing, and equipment and supplies to create a realistic environment" (Hayden et al., 2014, p. S38). Clearly, not just any simulation experience will provide the same results. But, done right, the use of high-quality simulation experiences as an effective teaching and learning tool appears to be legitimized by this study that demonstrated comparable end-of-program education outcomes and new graduates who are ready for clinical practice.

Game-Based Learning

Interactive gaming, serious games, digital games, technology-based games, casual games, computer-based games, simulation games, gamification—there is considerable variation in naming and defining the use of games in education, with many terms used interchangeably and depending upon the situation. For the purpose of this study, game-based learning (GBL) will be defined as any activity that is (1) interactive, (2) based on a set of agreed-upon rules and constraints, (3) directed toward a clear goal that often includes challenge, and (4) includes ongoing feedback that enables players to monitor their progress (Wouters et al., 2013).

Some of the literature draws a distinct line between game-based learning (GBL) and simulation (Charsky, 2010; Crookes, Crookes, & Walsh, 2013; Hoffman & Nadelson, 2010); however, for the purpose of this study, GBL will be discussed as an active, experiential learning method. Many similarities between game-based learning and simulation-based education exist, therefore they will be considered together. A list of ten attributes of games used for learning recommended by the Federation of American Scientists (2006, p. 18-20) looks remarkably similar to the ten features referred to earlier regarding the use of simulation for learning:

- Clear learning goals.
- Broad experiences and practice opportunities that continue to challenge the learner and reinforce expertise.
- Continuous monitoring of progress, and use of this information to diagnose performance and adjust instruction to the learner's level of mastery.
- Encouragement of inquiry and questions, and response with answers appropriate to the learner and context.
- Contextual bridging: closing the gap between what is learned and its use.
- Time on task.
- Motivation and strong goal orientation.

- Scaffolding: Providing learners with cues, prompts, hints, and partial solutions to keep them progressing through learning, until they are capable of directing and controlling their own learning path.
- Personalization: tailoring learning to the individual.
- Infinite patience.

Advances in technology have delivered computer and video games that embody many of these characteristics—and Americans spend millions of dollars and hundreds of hours playing games for entertainment. The idea behind game-based learning is to capitalize on the characteristics that make game playing fun and use them for educational purposes (Bauman, 2013).

Game players learn by doing, with immediate feedback about their progress along the way. Players have a certain amount of control over the game environment and are motivated to problem-solve by exploring different solutions or routes to the end goal. All of this exploration happens within authentic contexts, realistic environments that are becoming more authentic and more immersive with the advent of novel technology. Game-based learning has great potential for increasing motivation (Crookall, 2010) and enhancing learning (Wilson et al., 2009; Wouters et al., 2013). Game players are actively involved in their own learning and are motivated to play and practice repeatedly in order to achieve a clear goal; they have control over their environment and are likely to probe various solutions to a problem, realizing there may be more than one solution; basic skills are learned in-context and then built upon and transferred to a new context (Gee, 2007).

Initially, research focused on potentially negative aspects of gaming, i.e. the influence of violent games on aggressive behavior, time wasting, addiction, and social isolation (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012). Computer games are clearly here to stay and more recently, the focus has turned to the positive factors associated with gaming including motivation, engagement, learning, and skill enhancement (Connolly et al., 2012; Gee, 2007; Squire, 2003). Theories of effective learning suggest that learning is most effective when it is active, experiential, situated, problem-based, and provides immediate feedback (Boyle, Connolly & Hainey, 2011; Ericsson et al., 1993; Gee, 2007; Kolb, 1984; Onda, 2012). It seems likely, therefore, that interactive gaming can be used as a pedagogical tool to transform the way we prepare students of any discipline, but specific to this study, the way we prepare nursing students for clinical experiences and practice. This seems like a natural progression from experiential learning traditionally provided in the apprenticeship model as nursing students were immersed in bedside patient care—to experiential learning made possible with the use of immersive technology allowing nursing students to practice inserting a urinary catheter as the registered nurse in the hospital. This VR technology provides the opportunity for students to be fully situated in the practice setting and actively learning from the experience—without the threat of causing any harm to patients.

Game-based learning in nursing education has historically included simple pencil-and-paper in-class, board games, or interactive group games often used to review lecture content (Blakely, Skirton, Cooper, Allum, & Nelmes, 2009; Royse & Newton, 2007), and, more recently, on-line computer-based virtual worlds in which students create avatars and interact with others (Green et al., 2014). The focus of this study, however, is on a totally immersive virtual reality in which students are placed in the middle of the experience and given the haptics to actually interact with their environment to perform procedural skills with immediate feedback.

Students currently enrolled in higher education are already next-generation "Digital Natives" (Prensky, 2003); these students grew up using technology daily, they are comfortable with it and they expect it in their classrooms. On average, university students spend much less time reading than previous generations and thousands of hours playing video games and watching TV (Squire, 2003). In 300 interviews several years ago, Tapscott (1998) found common attributes among students raised on the Internet: they were described as inquisitive, tolerant, self-confident, highly intelligent, and experiential and they expect immediacy, structure, engagement, and visual and kinesthetic media with instruction. Digital Natives are different than the people our educational system—including the discipline of nursing—was originally designed to teach. As educators and "Digital Immigrants" (Prensky, 2003), it is important to address this difference in learning style and take advantage of technology to promote learning.

Games have been around for a very long time, most often used as entertainment. Gaming as a concept has been used in nursing education since the 1980s when nurse educators began trying various experiential approaches to learning (Crookes et al., 2013; Royse & Newton, 2007). Development and introduction of gaming technology provides educators with new opportunities to motivate and really engage students in their own learning. Discussion around gaming has at times focused on whether or not games should be "fun" with some educators fearing that games in the classroom promote entertainment rather than learning (Peddle, 2011; Royse & Newton, 2007) while others suggest students are likely to be more actively engaged in their own learning if they perceive it as fun (Fowler, 2008).

While some educational games may be used primarily to reinforce knowledge acquisition, others have been shown to foster critical thinking and creative-problem solving (Johnson, Adams Becker, Estrada, & Freeman, 2014), the same skills necessary for graduate nurses to function effectively in complex work environments. Educators generally agree that learning is most effective when students are actively engaged in their own learning; however, nursing education, like many fields of higher education, remains very conventional, largely dependent on didactic styles of information delivery (Blakely et al., 2009). Rather than the "guide on the side," many educators continue to function as the "sage on the stage."

Game-based learning in nursing education appears to exist on a continuum, from paper-and-pencil or casual individual or team games to technology-based or digital games, including highly immersive virtual worlds and simulations involving computer-generated animation and haptics (Figure 2.1). Similar to simulation-based education, research regarding the effects of gaming on learning outcomes is limited (Blakely et al., 2009; Connolly et al., 2012; Crookall, 2010; National Research Council, 2011; Nestel, Groom, Eikeland-Husebo, & O'Donnell, 2011).

Figure 2.1 Continuum of games and their use in nursing education

The literature on GBL in nursing, like early simulation research, tends to focus on student satisfaction and self-report of learning (Lynch-Sauer et al., 2011). Studies show that most nursing students enjoy the use of various games to promote learning; however, there is little empirical evidence of learning outcomes achieved with the use of games as an educational tool. This is not specific to nursing education; educational research in general is lacking regarding the use of games for learning (Wilson et al., 2009). It is also noteworthy that many studies discuss the importance of debriefing or reflecting on the learning experience when games are implemented as a learning strategy, either individually or as a group. However, just as the gaming language varies, debriefing may also take on several different meanings, depending on the game and who is facilitating it.

Advances in educational technology and GBL will continue to provide new and innovative opportunities for nurse educators to involve students in new learning strategies. The latest Horizon Report (Johnson et al., 2014, p. 42) lists *Games and Gamification* as one of six "Important Developments in Educational Technology for Higher Education" with a time to adoption of two to three years. As new technology develops, nurse educators will be presented with many new options beyond the more traditionally-accepted pedagogies and will be continually challenged to integrate games of various types into nursing education curriculum. As GBL develops, it will become increasingly important for nurse educators to validate the application of games to nursing education related to learning outcomes and transition to practice. Nursing education, like nursing practice, must be evidence-based.

Virtual Reality

Virtual reality will be considered separately, though briefly, in this review as it is central to the technology being tested. Most of the research in nursing education discussing virtual reality refers to virtual worlds or virtual simulations such as Second Life™ or CliniSpace™, where students create an avatar and interact with other learners and virtual patients, in an authentic and computer-generated setting (Ahern & Wink, 2010; Green et al., 2014; Sweigart et al., 2014). While this technology has shown promise as an innovative form of experiential learning, it does not provide the same hands-on, fully three-dimensional capability of the game developed and tested in this study with the intent of providing the user the opportunity to practice procedural skills. One study reported on faculty satisfaction with using virtual reality simulation for intravenous (IV) catheter insertion (Jenson & McNally Forsyth, 2012). Though it used a haptic arm device that allowed the user to palpate veins and virtually insert an IV catheter, this system used graphics displayed on a computer screen rather than fully immersive VR headgear. The VR technology developed and tested in this study is novel and there is a dearth of literature regarding anything similar currently in use in nursing education.

Deliberate Practice and Flow

Deliberate practice involves engaging highly motivated learners in well-defined tasks that are representative of the real world task—clinical practice, in this case, more specifically, demonstrating the procedural skill of catheter insertion—at an increasing level of difficulty, with informative feedback that is delivered immediately (Ericsson et al., 1993). The principles of deliberate practice lay the foundation for learning a skill of any kind and may be highly relevant for the way procedural skills are learned in nursing education (Clapper & Kardong-Edgren, 2012).

Rather than simply practicing a task repeatedly and mindlessly, deliberate practice consists of a highly structured activity aimed at improvement in performance in a particular domain (Ericsson et al., 1993). In other words, in order to show improvement in an activity, an individual must participate in organized, intentional practice. Ericsson et al. (1993) cited several conditions for optimal learning: learner motivation to complete the task and improve performance, taking into account preexisting knowledge of the learner when planning the learning activity, providing immediate informative feedback to learners, and having learners repeatedly perform the same or similar tasks with increasing difficulty. This repetition with intent is at the heart of deliberate practice. McGaghie et al., (2010) added the importance of well-defined learning objectives and minimum practice standards learners must achieve before moving on to another or more complicated task; the time to master the task will likely vary from one learner to another and the learner should have the opportunity to practice until mastery is achieved. McGaghie (2014) purports that when implementing deliberate practice with the goal of mastery learning, there is no room, nor any excuse, for mediocrity; with focused, deliberate practice, no one ends up "below the line."

Many aspects of the theory of deliberate practice parallel Csikszentmihalyi's (1990) explanation of "optimal experience" or "flow" and repeat several principles previously discussed related to simulation-based education and game-based learning:

- A challenge that requires skill in order to achieve it
- Clear goals
- Complete absorption in the activity
- Concentration on the task at hand
- Immediate feedback
- A sense of control
- Raising the stakes so the activity does not become boring.

If students can be drawn into the *flow* of learning with VR technology and GBL that help them practice procedural skills, perhaps mastery learning is more likely to occur.

Various studies have shown the benefits of deliberate practice for students in practice professions that are required to show competence in skill performance; several studies have demonstrated the notion that psychomotor or procedural skill practice distributed over time—and that includes immediate, corrective feedback—enhances skill acquisition and retention (Ackerman, 2009; Coughlan, Williams, McRobert, & Ford, 2014; Duvivier et al., 2011; Kardong-Edgren & Adamson, 2009; McGaghie et al., 2011b; Oermann et al., 2011).

Most of the current research on deliberate practice and its effect on learning outcomes has been done in the field of medicine; evidence is beginning to appear regarding the effect of deliberate practice on patient outcomes (McGaghie et al., 2011a). Nursing-specific research is limited, but nurse educators are beginning to realize the potential of deliberate practice in preparing students for practice. In one large, multi-site study of retention and transfer of cardiopulmonary resuscitation using short (ten minute) but monthly sessions of deliberate practice, Oermann et al. (2011) was able to show an increase in skill retention in nursing students that participated in deliberate practice versus those that did not.

Learning and improvement of performance is not a passive accumulation of experience but depends on active engagement in deliberate practice, "where aspiring experts acquire mental representations to monitor, control, and refine their performance" (Ericsson, Whyte, & Ward, 2007, p. 68). For deliberate practice to be effective, learners must be self-motivated, willing to take control of their own learning behaviors as well as understand the importance of constructing knowledge and understanding from their own experiences. All of these principles align with previously discussed essentials of both simulation-based education and game-based learning.

Practicing each step of a skill in the context of the entire skill is another important factor to consider when trying to improve specific aspects of a skill (van Gog, Ericsson, Rikers, & Paas, 2005; Onda, 2012). Situated cognition has been cited as crucial in developing hands-on practice in an authentic clinical environment (Onda, 2012). Deliberate practice combined with active learning in the simulation lab using high-fidelity manikins helps to promote this in-context, situated cognition and learning (McGaghie et al., 2010). As another form of experiential learning, game-based learning used for procedural skill practice may have the same effect.

The nursing curriculum is large and increasing regularly as we acquire new knowledge and technology. Consequently, nursing students—and their faculty—can easily become overwhelmed with all that students need to learn in a limited amount of time. Clapper and Kardong-Edgren (2012) discuss the need to provide students the opportunity to practice necessary psychomotor skills often—and require students to do so since simply providing the opportunity may not be enough. Deliberate practice may be a useful tool for nurse educators in helping all students attain and retain competence; acquiring deliberate practice through the use of game-based learning and technology may provide another avenue for nursing students to obtain this valuable practice time. Research is very limited in the nursing education literature regarding the effect of deliberate practice used to enhance student competence and retention of procedural skills (Oermann et al., 2011; Whyte & Cormier, 2014).

Experiential Learning and Cognitive Load Theory

It is difficult to discuss the use of simulation or gaming to promote learning without also considering cognitive load theory (CLT). It is also impossible to discuss deliberate practice theory as a premise for skill acquisition without considering CLT. Most educational researchers agree that in order to learn complex skills (i.e., maintaining aseptic technique throughout the process of urinary catheter insertion), instruction needs to focus on authentic tasks, be adaptive to the learner's individual needs and capacity, and support and motivate learners throughout the learning process (Hessler & Henderson, 2013; van Gog et al., 2005). Cognitive load theory suggests that learning occurs best in an environment that takes into account the student's existing human cognitive architecture (Sweller et al., 1998), the schema each student brings to the learning experience.

CLT is based on the premise that working memory is limited; learning is the accumulation of knowledge and addition of information to the long-term memory, which is unlimited in its capacity (Vogel-Walcutt, Gebrim, Bowers, Carper, & Nicholson, 2011). When a student is required to analyze, connect, or critically think about the steps in a procedure rather than just memorize them, the ability of working memory to process data decreases from seven elements (give or take two at one time) to three to five elements (Cowin, 2001). Students need schema in order to scaffold newly acquired information, thereby reducing working memory load; if students do not have the schema to support new information, then new schema must be developed within the working memory, requiring an increase in mental effort or germane cognitive load (Sweller et al., 1998). Skilled performance of procedural skills develops through building more and increasingly complex schemas; students combine elements consisting of lower-level schemas into higher-level schemas that eventually results in schema automation (Paas & Sweller, 2012). Once this automation occurs, the limitations of working memory no longer exist for learners because they are dealing with previously learned information stored in long-term memory, leaving working memory available for more complex material. These schemas are constructed through practice that is planned and deliberate. Schema construction and automation are therefore key factors in students' ability to demonstrate transfer of acquired knowledge and skills.

While we have little control over intrinsic cognitive load (the difficulty of the material presented), one strategy to help manage intrinsic cognitive load includes working from simple to complex, a method that is frequently used in teaching procedural skills. Cognitive load theory states that the way information is presented to students (extraneous cognitive load) greatly affects their ability to learn, retain, and transfer knowledge (Sweller et al., 1998). Game-based learning and simulation-based education, depending on how they are used to present information to the learner, can serve to either increase or decrease extraneous load. Nursing students are often overwhelmed by the amount of content knowledge they are expected to learn; how the content is presented to students, both in the classroom and in the clinical setting may assist students not only in their ability to learn procedural skills, but also with their ability to retain and recall this information when needed. Using concepts of CLT in nursing education would most likely be helpful in decreasing the additive, and frequently overwhelming, cognitive load of nursing students.

An interesting and potential advantage of the VR game developed and tested in this study is the ability to "artificially exaggerate and make salient the critical learning knowledge" (Dror, Stevenage, & Ashworth, 2008, p. 294). One of the features built into this game is the ability for students to see *germs*, in the form of green dots, falling from their hands and arms onto their sterile field throughout the procedure. Though this is a distortion of reality and an obvious exaggeration, it may reduce cognitive load by providing effective mental representations for students, optimizing cognitive resources and attention and helping students focus on the task at hand (Dror, Schmidt, & O'Connor, 2011).

Kolb (1984) discusses the importance of considering learning style and learning spaces when providing educational activities for students, but perhaps even more importantly, considering the concept of the learning spiral. Rather than presenting new procedural skills to students and expecting them to demonstrate competency on the same day, Kolb's theory would espouse the importance of spiraling back around to learning, building on what learners' already know—or strengthening their schema. Spiral learning promotes time to reflect on an experience and give it meaning, which can then be transformed by the learner into action, creating a learning experience that becomes broader and deeper; this type of learning promotes transfer of experiences to another context (Kolb & Kolb, 2009). There is research that would appear to confirm the idea of this spiral learning, that practice of skills should be spaced over a period of time rather than expecting students to master them at the time of training (Oermann et al., 2011; Spruit, Band, & Hamming, 2014). By engaging students in active, experiential learning and spiraling back to concepts, the cognitive load is decreased and they are able to use what they already know in order to build more and stronger schema; this in turn, may help students retain and be better prepared to transfer procedural skills to other (patient care) settings.

This directly aligns with the concept of constructivism, and even more specifically for a practice profession such as nursing, Kolb's (1984) theory of experiential learning in which the learner is provided the opportunity and encouraged to construct his or her own learning through the transformation of knowledge. In the field of nursing education, this experiential learning occurs when students are allowed to develop their own experiences and build upon them before they actually begin working with patients in the clinical setting. Teaching procedural skills and allowing students to practice those skills using this VR gaming technology is another method to immerse students in their own learning experience. In many ways, games are one of the oldest forms of experiential learning. And a core characteristic of games is that they are organized around *doing* (Squire, 2006).

Designed Experiences

A central theory when designing experiences for learning involves how players make sense of their digital experiences (Squire, 2006). For educators designing and using game-based learning, this "shifts the question from *delivering content* to one of *designing experience* so learners can construct their own learning" (Squire, 2006, p. 20). Educational games provide a rule-based system that students need to navigate and negotiate within as they develop understanding of academic content. This is a distinct contrast to traditionally-based classrooms where content is delivered by teachers and students are expected to demonstrate learning by passing exams based on that content. Game-based pedagogies hold a "situated, interactionist view of learning where players enter with understandings, identities, and questions, and through interaction with the game system, develop along trajectories toward more expert performance" (Squire et al., 2007). The question then becomes: how do we set up transformative learning spaces where students—in this case nursing students—can become the professionals they aspire to be with the skills they need in order to be successful?

Several of the aforementioned attributes of simulation, games and flow are present in the VR game tested in this study. The technology has been utilized to create a designed experience, intended to put learners *inside* the patient's room in order to virtually practice the procedural skill. These attributes include:

- Clear learning goal: students know they are expected to maintain aseptic technique throughout the procedure;
- Feedback, both ongoing and immediate: students can see "germs" falling, making it clear when the "sterile field" has been broken. An added advantage when considering cost and return on investment is that students receive this feedback without the need for faculty time and oversight;
- Time on task: a clock runs continually so students can see how much time they are spending in the procedure. This can also be used for competition and self-improvement with a leaderboard showing best times for trials completed correctly;
- Scaffolding: cues appear on the screen providing students options for the next step in the procedure;
- Context: students are completing the procedure *in* a patient's hospital room;
- Repetitive practice: the procedure can be completed as many times as the student is willing to practice in order to improve;
- Motivation: most nursing students are internally motivated to become proficient and provide safe care. Using VR technology with game-based

elements such as time and points to promote competition may help provide external motivation to spend time practicing;

- Controllable environment where learners can make mistakes without serious consequences: there are “critical points” built into the game where students are automatically returned to the beginning of the procedure to start again, giving learners the chance to correct the error and practice accurately;
- Control: learners have choices about how to proceed throughout the procedure and they have choice about when and how to practice. While the equipment must be available for use, faculty oversight is not necessary.

Using technology and game-based learning pedagogies as designed experiences may help transform nursing education as students are more actively involved in their own learning, using technology that they are comfortable with. For nurse educators, immersive gaming technology may be another tool we can use to help nursing students begin to understand what it means to *think like a nurse*.

Summary

There is consensus within the literature that teaching procedural skills in the laboratory, checking competence by a criterion-based checklist and then expecting nursing students to apply these skills proficiently and consistently in clinical practice is not realistic or evidence-based. Clinical practice opportunities are becoming more difficult to arrange as patient acuity increases and safety concerns limit what students are allowed to do in the clinical setting; nursing faculty shortages are also a contributing factor to this problem. In-hospital clinical rotations are very time- and resource-intensive and learning opportunities during clinical experiences are inconsistent at best. All these reasons contribute to general agreement that alternatives to traditional clinical approaches for learning in nursing education are necessary. Nurse educators must be primarily concerned with producing new graduates that can function safely while providing high quality care; completing procedural skills proficiently while protecting patients from harm is an important expectation of a graduate nurse.

Current research has provided substantial evidence that there is no significant difference in performance outcomes demonstrated by students that spend up to 50% of their clinical time in simulation-based education; it appears that simulation can be effectively substituted for traditional clinical placement in undergraduate nursing education. Game-based learning is a form of simulation that may provide an innovative opportunity for nursing students to practice procedural skills. Immersive VR technology will continue to develop, providing nurse educators new and potential opportunities to help transform individual student learning experiences as well as nursing education as a whole. This study provides the first step in determining the usability of current technology and its potential usefulness in practicing procedural nursing skills.

It is important and imperative that nurse educators explore the many options in the area of game-based learning, choose the best strategies for learning, and thoughtfully implement them. If nurse educators are going to truly transform nursing education with the goal of producing graduate nurses that can demonstrate competence and provide safe patient care when performing procedural skills, we must investigate, implement, and carefully evaluate new learning technology and strategies. This study is important because it contributes not only to filling the gap in the research regarding the usability of novel game-based VR technology to promote procedural skill development, but may also contribute to the research gap related to the use of deliberate practice in nursing education to develop students' procedural skill proficiency. Finding educational methodologies with the greatest impact in promoting learning and retention of procedural skills in undergraduate nursing students is important for patient safety and health promotion.

CHAPTER THREE: METHODOLOGY

The ability to provide safe, high-quality nursing care is an expectation of registered nurses. Undergraduate nursing students' ability to demonstrate proficiency in procedural skills requires student dedication to practice and faculty dedication to implementation of designed experiences that promote practice and skill development. Simulation-based education and game-based learning provide exciting and innovative experiential learning possibilities for students, allowing them to be fully immersed in their own learning. The technology explored in this study combines Oculus Rift VR headgear and wearable haptic technology with game-based elements in order to immerse and engage students in the experience of practicing urinary catheter insertion. This chapter will present an overview of the methodology utilized in this study of game-based virtual reality used for procedural skill practice, including the purpose of the study, research questions, sample, research design, and human subject considerations.

Purpose of the Study

This study is primarily a preliminary, exploratory analysis of the usability of a unique VR game as an innovative method for nursing students to practice procedural nursing skills. System usability as well as user experience and reactions to the gaming technology for practicing were elicited post-intervention. Information gathered from this study will be used to further develop and expand this technology as an educational tool. The study also provided an initial analysis of the effect of this technology on undergraduate nursing students' ability to demonstrate competence in maintaining aseptic technique approximately two weeks after completion of a practice session using the technology. Urinary catheter insertion served as the exemplar for this study.

Research Questions

The research questions to be addressed in this study include:

1. How do subjects rate the usability of a game-based virtual reality system for practicing urinary catheter insertion?
2. What is the user experience related to enjoyment, engagement, comfort, likelihood to practice, and preference compared to traditional practice on a task trainer?
3. Is there any difference in time spent practicing and/or number of procedures completed in sixty minutes when comparing subjects that practiced with the VR game to those that practiced on a task trainer?
4. Is there any difference in ability to demonstrate aseptic technique during urinary catheter insertion two weeks after completing practice sessions when comparing subjects that practiced with the VR game to those that practiced on a task trainer?

Participants and Sampling

The research was conducted using a purposive convenience sample of undergraduate nursing students currently enrolled in a baccalaureate degree nursing program at a northwestern university. Inclusion in the study was directed at students currently enrolled in the fifth and sixth semesters of an eight semester program. This group of students was intentionally recruited for several reasons:

- Because of their place in the program, these students had previously demonstrated competence in urinary catheter insertion using a criterion-based checklist, which served as a baseline for this study.
- The purpose of this system is to practice catheter insertion in order to reach and maintain proficiency in demonstrating aseptic technique, not to *teach* students how to complete the procedure.
- All students in fifth or sixth semesters were concurrently enrolled in an acute care clinical rotation in which they may need to demonstrate aseptic technique (but had most likely not yet had much experience that would affect the study results).
- Students in each semester of the program are scheduled for different clinical days so it was hoped that focusing on students from different semesters might help with their ability to schedule research study appointments.

As a usability study of the technology, a sample of five participants is considered sufficient to collect the most efficient and cost-effective information in the iterative process of system development (Nielsen, 2012). However, because the development team and the system itself were available for a limited amount of time, essentially at no added cost to the university, and because the secondary goal of the study was to compare post-intervention effect, this study included ten subjects in the experimental group with ten subjects in a control group in an attempt to promote the most valuable initial data collection.

Human Subjects' Protection

Expedited review and approval by the university Institutional Review Board (IRB) was applied for and granted prior to recruitment of participants, Approval #187-SB15-034 (Appendix B). Participants for the study were recruited face-to-face by the researcher during one of the students' lecture classes, at which time students were given the opportunity to ask questions about the study and have them answered by the researcher. Students were informed that video images would be digitally recorded throughout the study, resulting in the inability to provide anonymity; they were also reminded of the waiver they routinely sign as a student involved in learning in the simulation center (Appendix C). Students were informed that there would be no personal direct benefits to participation in this study and assured that participation was entirely voluntary and without any consequence related to their grades. Potential subjects were also assured that the information gathered in this study would be used for educational purposes only and that no specific information about individual performance would be shared with other faculty or administration in the School of Nursing.

Finally, students were informed of the potential benefit of their participation to help develop new teaching and learning methods using technology to practice procedural skills (Appendix D). Once all questions and concerns were thoroughly addressed, willing participants were asked to sign Informed Consent (Appendix E) and enrolled in the research study. Anticipating attrition due to scheduling difficulties, all thirty-six volunteers completed Informed Consent and the initial survey in an attempt to ensure a final sample of twenty students.

Research Design

This mixed methods research study used a triangulation design convergence model. Different types of data from two different surveys were collected and combined with observation during system use in an attempt to form an overall interpretation of the system (Creswell & Plano Clark, 2007). The primary purpose of the study was to explore the usability of this game-based technology and to elicit user-reaction to practicing a procedural nursing skill using the VR game. A secondary goal was to compare the effect of practice on a task trainer versus practice using VR technology on students' ability to maintain aseptic technique during demonstration of urinary catheter insertion approximately two weeks after completion of the practice session, keeping in mind this is a very small sample.

Instruments

System usability was measured post-intervention using an established tool, the System Usability Survey (SUS, Appendix E). The SUS (Brooke, 1996) is a simple ten-item scale that provides a high level of face validity by asking for immediate responses on several aspects of system usability, i.e. effectiveness, efficiency and satisfaction. The SUS score, ranging from 0 to 100, is a composite measure of the overall usability of the system and reflects a standard letter grade scale: products or systems that score in the 90s are considered exceptional, those that score in the 80s are good, and products or systems that score in the 70s are acceptable (Bangor et al., 2009). The SUS is considered highly reliable (alpha = .91) and the score becomes easier to interpret with the addition of an adjective rating scale with a correlation value of r = 0.822 (Bangor et al., 2009).

A user-reaction survey (Appendix F) was utilized in combination with observations of participants while practicing with the VR game in order to measure enjoyment, engagement, physical comfort related to the equipment, likelihood to practice, and preference compared to practicing on a task trainer. Verbal responses during practice sessions were digitally recorded and then transcribed, coded, and considered along with responses to the surveys and player movement within the game during practice.

Procedure

After Informed Consent was obtained, each study participant completed a brief demographic survey that included age, gender, ethnicity, semester in the nursing program, overall grade point average, and several questions about game-playing behavior and comfort with technology and learning with simulation (Appendix G). Initially, based on information from the demographic survey, a matched-pair design was used to assign subjects to a control or treatment group in an attempt to enhance group similarity. However, due to scheduling difficulties for many students resulting in subsequent attrition from study participation before it even began, the remaining study slots were filled randomly from the pool of thirty-six students originally recruited. In the end, both control and experimental groups consisted of ten participants each for a total of twenty study participants.

Control Group

Participants assigned to the control group self-scheduled a one-hour practice session in the simulation center supervised by an experienced faculty member; during this time, participants were given the supplies needed to practice urinary catheter insertion on a partial task trainer with immediate feedback on performance from the faculty. Using a web-based scheduling tool, students were initially given two appointment options (again, due to anticipated scheduling difficulties), providing a student to faculty ratio of five to one; a typical practice session in this School of Nursing would be ten to one, however getting all participants in the lab at one time for this study was not possible. Due to further scheduling difficulties, in order to maintain a control group of ten subjects, an additional session was created, thus decreasing the student to faculty ratio to three or four to one. Two sessions were overseen by the same faculty member while the final session was run by a different faculty member; the principle investigator was not involved in any of the sessions other than to provide initial instruction to faculty.

Faculty were asked to instruct student participants to work in pairs or trios to practice catheter insertion; the student(s) not practicing hands-on insertion were asked to act as peer evaluators, watching for breaks in aseptic technique and providing feedback on performance. The faculty role was to provide expert feedback regarding overall insertion technique with specific attention paid to students' ability to maintain aseptic technique throughout the procedure. Each practice session was digitally recorded and reviewed for time-on-task and number of completed procedures in one hour. Conversations and behaviors during practice time were also recorded and reviewed.

Experimental Group

Each participant assigned to the experimental group individually self-scheduled a one hour appointment in the simulation center. Upon arrival, each participant was assisted into the Oculus Rift headgear, wearable haptics, and sensory gloves; this process averaged approximately six minutes in order to synchronize and calibrate the equipment to each subjects' movements. Once situated in the equipment and initially acclimated to the VR sense of immersion, participants were talked through the virtual catheter insertion procedure. For example, subjects were encouraged to experiment with various commands (i.e., focusing on a table in order to move it closer), movements (i.e., timing of pinching and releasing) and location of "hotspots" within the game (i.e., points to pinch in order to move forward in the procedure), all of which were required in order to function in the virtual world. This orientation to the game took 10-15 minutes the first time through the procedure.

Following this orientation, participants were instructed to use as much or as little of the remaining hour to practice catheter insertion virtually; each subject was reminded that the practice session could be concluded at any time the participant became uncomfortable or simply chose to stop. Reminders regarding game mechanics were provided throughout the practice session as needed. Each session was assessed in real-time for any signs of distress, enjoyment, or other overt behaviors in addition to being digitally recorded for more careful review. Each player's movement within the game was captured and recorded two-dimensionally on the computer screen, providing the ability to track time on task and number of completed procedures.

Following completion of each practice session (either at the completion of one hour or when the participant chose to stop practicing before that), each participant completed a System Usability Survey (Brooke, 1996) plus adjective rating scale (Bangor et al., 2009) to assess effectiveness, efficiency, and satisfaction with the system itself. Each participant also completed a survey regarding user experience with the technology related to enjoyment, engagement, physical comfort with the equipment, likelihood to practice, and preference compared to practicing on a task trainer.

Follow-up

Approximately two weeks after completing the practice session, all study participants (control and experimental) self-scheduled a brief return appointment to the simulation center. Each participant answered two questions regarding any further practice or actual experience placing a urinary catheter since study practice session. During this 10-15 minute session, each participant demonstrated insertion of a urinary catheter on a partial task trainer using the equipment provided. Demonstration equipment and supplies were the same as those used by the control group participants, essentially the same as equipment used in the VR game. Each demonstration was digitally recorded and timed from start of procedure to finish. Demonstrations were scored by a blinded subject matter expert/reviewer using a criterion-based checklist traditionally used in the School of Nursing, modified slightly for this study (Appendix A). A second blinded subject matter expert/reviewer scored five demonstrations randomly selected to assess for inter-rater reliability. The study design is shown in Figure 3.1.

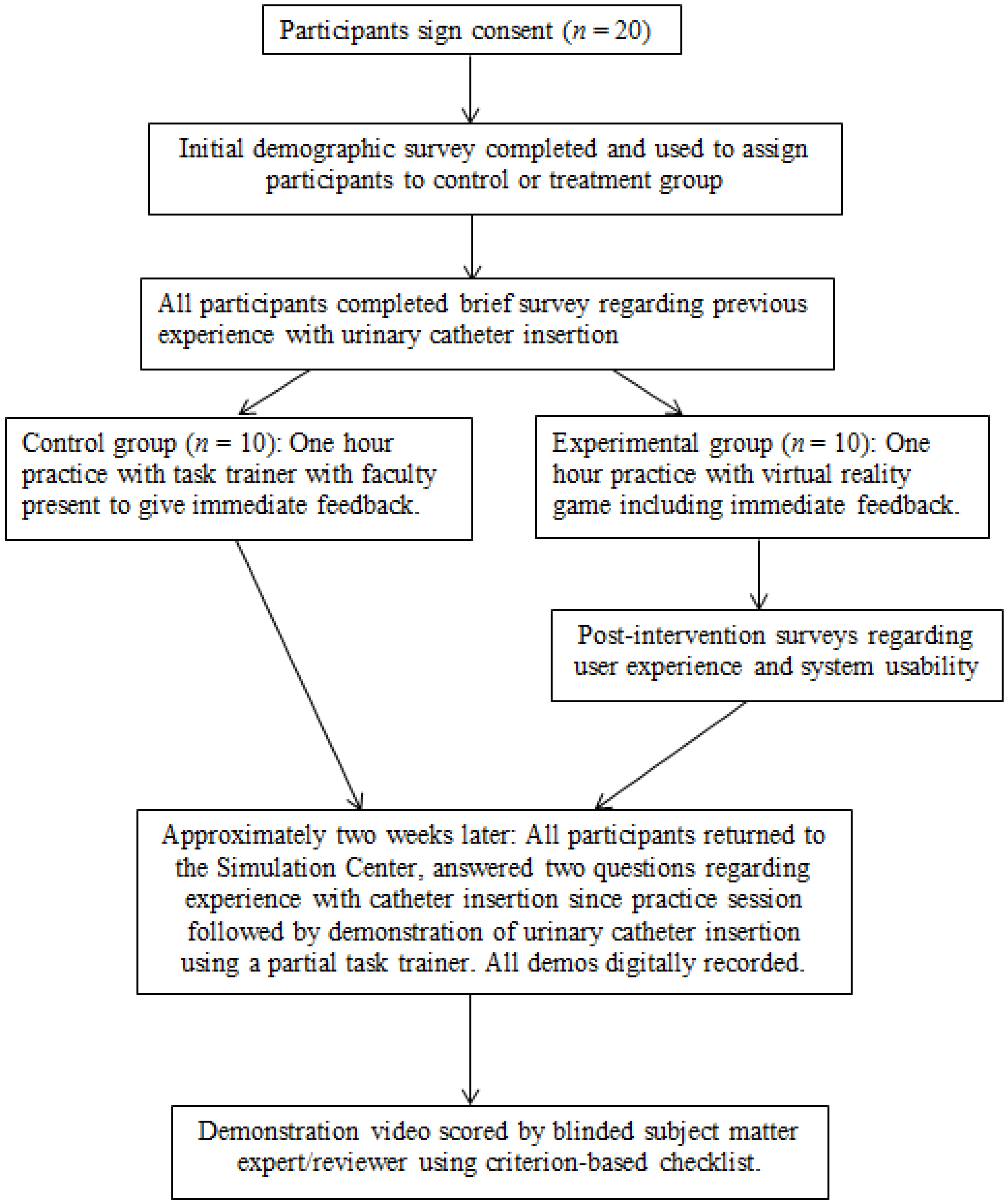

Figure 3.1 Study schematic

CHAPTER FOUR: RESULTS

The primary purpose of this study was to explore the usability of a unique virtual reality game as a method for undergraduate nursing students to practice procedural nursing skills, using urinary catheter insertion as an exemplar. Usability includes effectiveness, efficiency, and user satisfaction with the system itself (Brooke, 1996). This study also measured user experience and reactions to the game-based virtual reality technology regarding enjoyment, engagement, comfort, likelihood to practice, and preference compared to traditional practice on a task trainer. The study compared practice time-on-task and number of procedures completed between students that practiced on a task trainer versus those that practiced with the VR game. Finally, the study provided an initial analysis of the effect this technology had on undergraduate nursing students' ability to demonstrate competence in maintaining aseptic technique approximately two weeks post-practice compared to students that practiced with a task trainer. This chapter presents descriptive statistics of the sample and results related to each research question including survey frequencies and themes extracted from observations and user-reaction surveys.

Study Sample Characteristics

Descriptive statistics were used to define the sample (Table 4.1). The Statistical Package for the Social Sciences (SPSS) 22 (IBM Corp, 2013) was used to code responses to the initial survey and summarize information. Undergraduate nursing students (n=20) enrolled in a traditional four-year baccalaureate nursing program voluntarily participated in the study; all twenty students completed the study. Fifty-five percent of subjects were 20 to 25 years old with the remaining 45 percent ranging from 26 to 48 years of age. Of the 20 study participants, 16 (80%) were female while 4 (20%) were male, a gender distribution that is not representative of the nursing population in the United States as nationally, only 9 percent of all nurses were men in 2011 (U.S. Census Bureau, 2013). The mean overall grade point average (GPA) was 3.64 (SD = .3575) and ranged from 3.0 to 4.0 with the majority of students (70%) between 3.6 and 4.0 on a four point scale. The sample was almost evenly split with 60% of the subjects enrolled in the fifth semester and 40% in their sixth semester of an eight semester nursing program. Due to scheduling complications, the groups were dissimilar in the percentage of students from each semester. In the Deliberate Practice/control group, the number of catheter insertions on a manikin ranged from 5-15 (m = 9.9, SD = 3.107) while the VR game/experimental group ranged from 4-12 (m = 7.2, SD = 2.440); number of previous insertions on a human was similar at less than one for each group. Thirty-five percent of subjects considered themselves “gamers” while 65% reported feeling both “very comfortable with technology in general” and that “simulation really helps me learn”; the remaining 35% felt “OK” with technology and neutral regarding simulation for learning. The sample was predominantly Caucasian.

Table 4.1
Descriptive Statistics for Sample

	DP/control group (n= 10)	VR game/ exp group (n = 10)
Age	Mean: 28.4 Range: 20-48 SD: 9.407	Mean: 27.1 Range: 20-41 SD: 7.549
Gender	Female: 8 Male: 2	Female: 8 Male: 2
Ethnicity	Caucasian: 9 Non-Caucasian: 1	Caucasian: 9 Non-Caucasian: 1
GPA	Mean: 3.59 Range: 3.0-4.0 SD: .425	Mean: 3.69 Range: 3.2-4.0 SD: .288
Semester in program	5^{th}: 30% 6^{th}: 70%	5^{th}: 80% 6^{th}: 20%
Comfort w/technology	Mean: 1.6* SD: .425	Mean: 1.7* SD: .483
Comfort w/simulation	Mean: 1.6* SD: .425	Mean: 1.7* SD: .483
Manikin insertion	Mean: 9.9 Range: 5-15 SD: 3.107	Mean: 7.2 Range: 4-12 SD: 2.440
Human insertion	Mean: 0.9 Range: 0-2 SD: .876	Mean: 0.8 Range: 0-3 SD: .919
Self-reported "Gamer"	Yes: 40% No: 60%	Yes: 30% No: 70%

*1= "OK", 2= "Very comfortable" (No study participants selected "uncomfortable" for either measure)

Question 1: How do subjects rate the usability of a game-based virtual reality system for practicing urinary catheter insertion?

All subjects in the VR game group completed the System Usability Survey (Brooke, 1996) with added adjective rating scale (Bangor et al., 2009) immediately upon completion of their practice time. Survey scores ranged from 42.5 to 92.5 with a mean of 72.5 (SD=14.907), placing the system in the "Acceptable" range. Overall adjective rating ranged from *Poor* (10%) to *Best Imaginable* (10%) with 80% of subjects rating the system either *Good* or *Excellent*. SPSS 22 (IBM Corp., 2013) was used to generate frequency comparisons on each of ten individual survey items (Appendix I). These comparisons show general agreement on ease of use (90% agree or highly agree), confidence using the system (80% agree or highly agree), and desire to use the system frequently (80% agree or highly agree). However, users also believed they would need tech support in order to use the system (70% agree or highly agree)—one respondent wrote on the survey next to this question "just for set-up." This factor clearly influenced overall usability scores.

Observations of the participants while working within the system revealed recurrent themes related to the SUS. Students appeared to make their way around the game quite easily, cutting procedure completion time from an average of approximately 12 minutes from first run-through (range 8-16 minutes) to 7 minutes (range 4-9 minutes) on second procedure completion. Some students were completing the procedure in 3-4 minutes on subsequent trials as their understanding of the game increased along with the efficiency of their movements. Most participants appeared satisfied with the VR game and were willing to repeat the procedure several times in order to improve their score despite any technical/equipment "glitches."

> Student 1, when asked about frustration with finding tear points on the packets and the need to restart the procedure due to the system: *No, it's not frustrating, it's cool! It's just about learning how to use it.*

> Student 3: *That was good, thank you, I appreciate it. I can't wait to see it and do it again*.

> Student 7 rated self as a "gamer" and stated: *This is really impressive. I could definitely realize right away everything that was going on even though it didn't look like actually putting in a catheter.*

Question 2: How do users rate their experience related to enjoyment, engagement, comfort, likelihood to practice, and preference compared to traditional practice on a task trainer?

Immediately after completion of their practice session, all subjects in the VR game group also completed a user-reaction survey that included 24 items on a Likert scale plus two open-ended questions. Frequency comparisons for each of the questions (Appendix J) revealed agreement that subjects believed the VR game was fun (100% agreed or strongly agreed), engaging (100% agreed or strongly agreed), and made them lose track of time (100% agree or strongly agree). Subjects were not bothered by the headgear (100% agreed or strongly agreed), however two students agreed (10%) or highly agreed (10%) that practicing with the VR game “was physically uncomfortable”; one student added “a little nauseous” next to the question while the other wrote in open-ended question that she felt “sick and dizzy.”

Ninety percent of participants found it difficult to concentrate on maintaining aseptic technique while using the VR game and subjects were split over preference to “practice on a task trainer with faculty feedback” (60% disagreed, 40% agreed). Even so, 70% of the students either agreed or strongly agreed that they would “be more likely to practice catheter insertion using this game than a task trainer” and 100% either agreed or strongly agreed that “practicing this way will help me insert a catheter correctly.”

Several of these themes recurred in the transcripts of observations of students during practice sessions and related themes appeared, i.e. motivation, competition, focus during practice, feedback, willingness to practice repeatedly, development of confidence in gameplay, as well as remembering procedural steps.

Student 1: *This is just so different (smiling). It's cool, I'll do it again! It's fun, I like it. Thank you!* This student was very patient with technical difficulties with the game; she denied becoming frustrated with the "glitches" and was anxious to continue to practice. After her follow-up demonstration, this student happily offered this comment: *I was picturing the steps in the game—I learned!*

Student 2: *Oh my gosh (smiling), this is so weird (laughing). It felt much better the second time through—yeah, I'll do it again. Cool, that was awesome, thanks!*

Student 3: *Getting used to it might be a struggle—but I think it's a pretty good tool, especially once you get used to it. That was good, thank you—I can't wait to see it and do it again.* This student complained of shoulder discomfort from holding arms up through five procedure completions, however he was very determined to get the best score and did not rate the system as uncomfortable stating at one point: *I could do one or two more runs if I hurry.*

Student 4: *I gotta be honest with you, I feel a little nauseous—but it's cool! The technology is really cool, just for me it was a little bit of a struggle.* This student made it through the procedure twice before ending the practice session at 28 minutes due to discomfort.

Student 5: *Look, I'm dripping green stuff—and there's an exclamation point because I broke sterile field! (smiles).* This student laughed out loud the first time the table moved towards her, moving her head around to experiment with moving from one station to another in the room. *I'm pretty sure I can do it faster than that—it took me like fifteen minutes!* And after the second run-through: *I felt more confident about it, like where stuff was and how it worked and more confident about how to adjust to what I was seeing and what my body was actually doing. I think it doesn't teach you sterile technique super well besides the green dots—but that's just because the technology is hard to be precise. Thanks! It was very interesting and kinda fun.* Survey comments included: *I was motivated to do it faster, motivated to remember the steps. I feel like you miss out on how difficult it is to put gloves on and what it is like to actually insert the catheter into the person. If they could incorporate that in some way, it might help prepare us better.*

Student 6: *It feels weird because I want to step to the side but then I'm supposed to look at it instead. The more I go through it, the more comfortable I get. I feel fine, let's do it again. The more I do it, the more I think about what step I need to do next. I thought it was cool, different than doing DRP* (traditional practice). *It was fun, thanks for the experience!* This student was a "gamer" and offered several suggestions to developers about how to improve the game. Survey comments: *Practicing this way compared to on a manikin was a lot more fun. I felt motivated to improve my time and score.*

Student 7: *Oooh, that's interesting (learning to move around in room). I do not like that part (movement). That was pretty weird—very cool, but weird. Really surprised how quickly I got used to it actually*. This student completed procedure once then stated: *Umm, I'm good, it's kinda giving me a headache so….the way it moves too, my shoulders are kinda sore*. Survey comment: *I felt like I could take my time. I didn't worry about wasting materials or going too slow*. Suggestion*: A tutorial on how to use the techniques would have been helpful—I'm so used to video games having tutorials that I expected this to have one.*

Student 8: *Whewhoo! That's awesome! Definitely easier the second time. I wanna do one more time to see if I can beat my time—what was the best run? That was fun, that was so cool. Oh my gosh, that is so cool! (laughter) I've seen virtual reality in movies but haven't ever used it, this is really cool! I'll try again, for sure!* Wrote in capital letters on SUS: *SO FUN!* Offered suggestions for feedback: *I noticed that when sterile technique was not followed, all that would happen was a yellow light and a "Caution" sign would pop up. I think a useful change would be an auditory alert and then it tells you what you did wrong*.

Student 9: *Ooooh, that's cool! (laughs and repeats that is so cool several times while learning how to move in the game). Ready to go again? I'm doing it again, can I just keep the stuff on and do it again? I don't need a break. So, how many times do I get to do this? I have to beat XXX, I think she got the best time yesterday*. Survey response: *The overall experience was great and I felt like I was in a different world. I believe this type of sim would be good for repetition but not for someone's first time placing a catheter. You should identify when you have become unsterile with a BIG RED X in front of your face. Had fun. Thank You.*

Student 10: *That's pretty cool. So how many times do I get to do this? That's pretty cool, it felt like it was actually right here—I wasn't expecting to see it when I put this on. This is so not what I thought it would be—I thought we'd be on the computer or something. This is way better, WAY better. I really wanna beat my friend—she said there's no way, I said "we'll see about that!" (laughter). This is definitely good for people that are just learning the steps, it's beneficial for repetition of the steps. You could do this with a whole bunch of things like IVs and central line dressing changes. I think this would be a great addition to manikins*. After completing seven procedures: *I think I'm good, thank you. And if XXX comes by, you have to tell her I beat her!*

Question 3: Is there a difference in time spent practicing and/or number of procedures completed in sixty minutes when comparing subjects that practiced with the VR game to those that practiced on a task trainer?

Video recordings of all practice sessions were reviewed in order to document the number of procedures completed by each study participant in one hour. Videos were also reviewed to document time-on-task (minutes spent actually practicing the procedure, start to finish) in one hour. This data was recorded for each individual VR game participant as well as each student in each DP control session.

The mean practice time and procedure completion are reported in Table 4.2. The mean practice time was significantly greater for the VR game group (M = 25.3 minutes, SD = 5.889) than for the DP group (M = 14.9 minutes, SD = 6.172), $t(18) = 3.86$, $p = .001$. The mean procedures completed was also significantly greater for the VR group (M = 3.9, SD = 1.287) than for the DP control group (M = 1.8, SD = .422), $t(18) = 4.90$, $p < .001$. These data are shown using Box Plots in order to clearly visualize the comparison (see Figures 4.1 and 4.2).

Table 4.2
Comparison of time-on-task and procedures completed

Report

group		Practice time (minutes)	Procedures completed
VR game	Mean	25.3000	3.9000
	N	10	10
	Std. Deviation	5.88878	1.28668
	Minimum	17.00	2.00
	Maximum	37.00	6.00
Control DP	Mean	14.9000	1.8000
	N	10	10
	Std. Deviation	6.17252	.42164
	Minimum	10.00	1.00
	Maximum	31.00	2.00

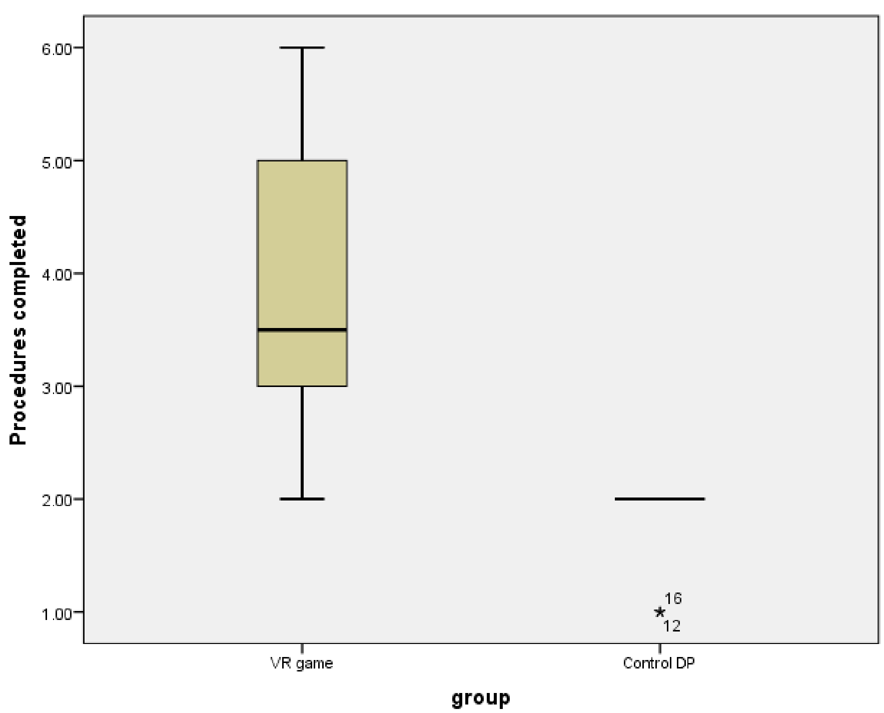

Figure 4.1 Box Plot of procedures completed for each group

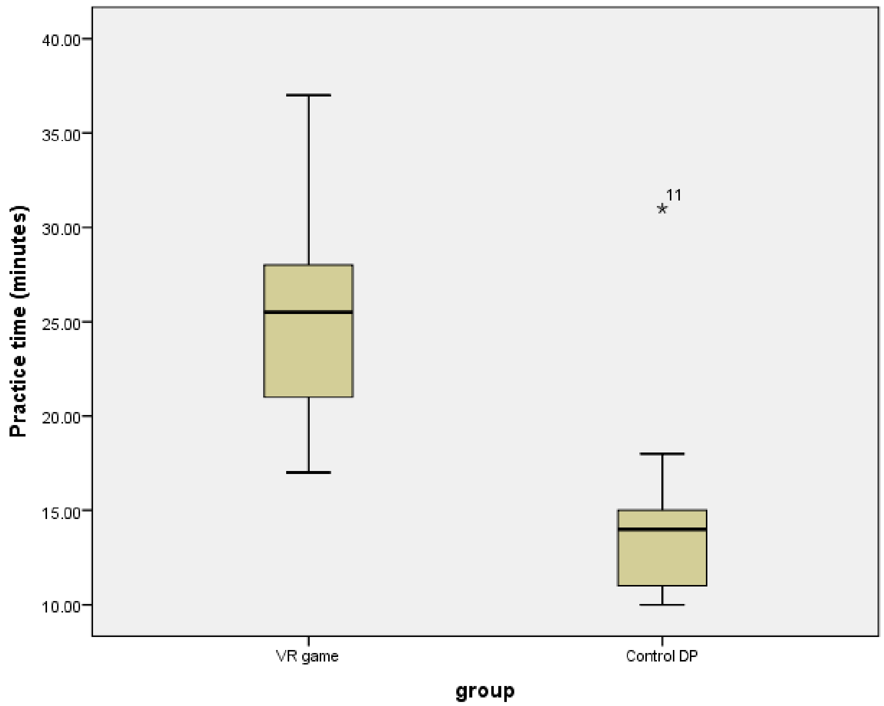

Figure 4.2 Box Plot of time-on-task for each group

Students in the VR game group worked individually and, after calibration and syncing of the equipment, had approximately 45 minutes remaining of their hour to practice. Other than two students that stopped practicing due to discomfort with the movement of the game, all participants used their full hour to practice, all reported losing track of time and being engaged in their learning.

During practice sessions in the DP control group, students practiced in pairs or trios with one faculty member available to oversee their practice and provide immediate feedback. Students were reminded that when they were not physically practicing, they should watch their peers in order to learn from them and offer constructive feedback. Conversation in the room during practice sometimes centered on the task-at-hand, however there were many times during observation when discussion with peers and/or faculty was off-topic (i.e., classes, work, experiences with the procedure versus the procedure itself). Self-reflection on the process was observed at times, along with specific requests to faculty for feedback from students. Almost all observed feedback came from faculty with very little offered by student peers. Students in the SON know that cost prohibits use of new kits for each individual demonstration, therefore each student spent several minutes of their hour picking up and repackaging their kits rather than actually practicing the procedure or observing their peers. Students in the DP group were observed looking at the clock or their watches and some were distracted by students walking by in the hall; many stood passively watching their peers rather than offering feedback to each other. All DP group participants left the practice session after completing a maximum of two procedures whether the hour was up or not.

> Students 11, 12, and 16: Student 11 struggled with the procedure, asking numerous questions of faculty throughout the hour and practicing twice during the hour for a total of 31 minutes. Students 12 and 16 offered minimal feedback during this time, spending more time talking with each other and faculty during the hour. Each of them (12 and 16) spent approximately ten minutes actually practicing during the hour and each completed the process once.

> Student 12: *Why do I get so nervous? I'm not even getting tested and I'm nervous.* This student also appears self-conscious with peers and faculty watching.

> Students 13, 14, and 15: All students completed the procedure twice for a practice time of approximately 15 minutes each, 45 minutes total. At one point, all three students were cleaning up and repackaging kits, talking about work. This group spent several minutes of the hour asking questions and discussing different aspects of the procedure, usually with faculty while one of the other two students was actually practicing the procedure. At one point, Student 15 stated: *So we can do it again if we want? I'll go after you, go ahead.*

> Students 17-20: Two students arrived late and stood in the door to wait while Students 19 and 20 were each practicing the procedure on a manikin. At this point, students were asked to work in pairs and observe their peers. Students 19 and 20 completed the procedure they had started and then repeated the procedure immediately. While they were cleaning up, Students 17 and 18 took a turn and

then immediately repeated the procedure. This group had several minutes of loud conversation/discussion. There were also times when students were quiet and appeared focused on the procedure. All four students completed two procedures and ended the practice session at approximately 45 minutes.

Student 17: When asked if it felt better the second time: *Yes, for sure!*

Student 18: Quietly practiced, appeared focused and specifically requested feedback from faculty upon completion: *Other than holding the syringe so it doesn't refill, any comments?*

Student 19: Moved through the procedure the first time without any feedback (faculty was with Student 20, other students not yet present). When finished, faculty voiced concerns about "gaps in sterile technique," student looked confused, perhaps unsure about what she did and/or didn't do. After the second run-through, student looked for feedback from faculty.

Student 20: *Upon arrival: Oh, this is a different kit—are you ok if we tear these open?* To faculty: *If you were me, where would you pour this (lubricant)? We're not used to not having a bag to catch the urine (laughs).* After practicing twice, stated: *I'll do it again—oh wait, if everybody else is leaving, I'll go too.*

Question 4: Is there a difference in ability to demonstrate aseptic technique during urinary catheter insertion two weeks after completing practice sessions when comparing subjects that practiced with the VR game to those that practiced on a task trainer?

Approximately two weeks after the initial practice session, each study participant returned to the simulation center for a follow-up demonstration of urinary catheter insertion. All demonstrations were digitally recorded and scored by a blinded reviewer using the criterion-based checklist utilized by the School of Nursing for skills validation. All twenty study participants were scored and given either a pass or fail based on the checklist. A second blinded reviewer scored five randomly chosen demonstrations in an attempt to assess for rater agreement. Using SPSS 22 (IBM Corp., 2013), Cohen's kappa was measured at .545 showing moderate agreement between raters (Laerd Statistics, 2015). Pass rates between groups was identical at 60%.

Summary of Findings

A purposive sample of 20 undergraduate nursing students in the fifth and sixth semester of an eight semester baccalaureate program participated in this mixed method study. The primary purpose of the study was to determine the usability of a game-based virtual reality system for practicing procedural skills, specifically urinary catheter insertion. All twenty students signed informed consent and all students completed all parts of the study. Analysis of the demographic data confirmed similarity of groups except for semester representation with the DP control group having a higher percentage of sixth semester students. Self-reported experience with catheter practice on a manikin and insertion on human patients demonstrated that students had similar experience regardless of semester placement.

Study participants rated overall usability of the system in the *Good* to *Excellent* range. Subjects agreed that practicing with this VR game was enjoyable and engaging. Most participants did not find the system uncomfortable, however the movement within the game was an issue for two of the students who reportedly liked the game but complained of either headache or dizziness after use. The group did not agree on preference to practice with the VR game versus traditional practice on a manikin, but 70% agreed that they would be more likely to practice catheter insertion using this game. The VR game subjects practiced significantly more minutes and completed significantly more procedures than the DP control group. Observations and analysis of themes that emerged during practice supported the survey data. In addition to enjoyment, engagement, comfort, preference, and likelihood to practice with the VR game, other themes included motivation, competition, feedback (the need for more in the game), and developing confidence. The VR game group practiced the procedure significantly more than the control group; interestingly, the follow-up demonstration pass rate for both groups was 60%.

CHAPTER FIVE: DISCUSSION AND IMPLICATIONS

Learning to perform procedural skills safely is a primary responsibility of undergraduate nursing students. In order to become competent and confident in their skills, student nurses need to practice. Promoting procedural skill development while ensuring patient safety is an ongoing concern and primary responsibility of nurse educators.

Simulation-based education in nursing has become an accepted and rather commonly used teaching methodology to help prepare student nurses for practice in a complex health care environment. Simulation provides a realistic patient care environment where student nurses can *practice* on manikins and task trainers prior to *practicing* with patients. Simulation can take many forms, but one of the goals of all forms of simulation is to give students the opportunity to actively participate in their own learning experience. For this study, game-based learning was considered one form of simulation-based education that shares several of the same features of SBE including clear learning goals, immediate feedback so learners can monitor their progress, increasing difficulty, and the opportunity for repetitive practice (Issenberg et al., 2005). In addition, game-based learning includes challenge, motivation, scaffolding—and infinite patience (Federation of American Scientists, 2006).

The development team hypothesized that combining game-based learning elements with the latest virtual reality technology could provide educators a new and innovative way to help students deliberately and repetitively practice procedural skills. The purpose of this study was to explore the usability of, and user reaction to, a game-based virtual reality system designed to practice one such procedural skill. This VR game uses Oculus Rift headgear and wearable haptic technology to immerse and engage the student in the experience of catheter insertion—the student is *in* a patient's room, practicing the procedural skill virtually. This study was an initial analysis of the first iteration of this unique game-based VR system.

This chapter provides a summary and discussion of the findings related to the study research questions. The chapter also includes discussion of the strengths and limitations of the study. Finally, this chapter discusses implications for nursing education and research with recommendations for further study.

Summary and Discussion of the Findings

Four research questions formed the basis of this study exploring the use of a virtual reality game as a method to help undergraduate nursing students practice procedural skills, using urinary catheter insertion as exemplar. Each question and related study results will be addressed separately.

This study combined descriptive statistics and qualitative data to form an overall interpretation of the usefulness of the game-based VR system as a learning tool. A triangulation design convergence model was used to compare, contrast, and corroborate results from a System Usability Survey (Brooke, 1996) with added adjective rating (Bangor et al., 2009) and a user reaction survey completed immediately after use of the VR game with direct observation of subjects' reactions while practicing catheter insertion within the VR game.

Question 1: How do subjects rate the usability of a game-based virtual reality system for practicing urinary catheter insertion?

Participants' ratings on the SUS were highest in the categories considering ease of use, desire to use the system frequently, well-integrated functions, and confidence using the system. Along with rating the system easy to use, participants also reported feeling the need for support from a tech person to use the simulation, with one participant adding "only for set-up." Rather than including a tutorial (as many video game players are accustomed to), for the first iteration of the game participants were set-up in the system and walked through the first run-through of the game by one of the members of the development team. Participants did, in this case, need help with tech support, something to be considered going forward. It is possible to set-up a profile for each participant ahead of time so that when they go in to practice, the system would recognize them and there would be no need for a tech support person to help with calibrating and syncing the system as occurred in this trial run. Low ratings in this category influenced the overall SUS score. Despite consistently low scores in that category, participant ratings of the VR game averaged 72.5, ranging from 42.5 to 92.5. This rating places the system in the *Acceptable* range or, using the adjective rating scale, in the *Good* to *Excellent* range.

Question 2: What is the user experience related to enjoyment, engagement, comfort, likelihood to practice, and preference compared to traditional practice on a task trainer?

Study participants gave the VR game high ratings in the attribute categories of enjoyment, engagement, and comfort (related to wearing the headgear), although two subjects of ten reported either slight nausea or dizziness. Observations of these participants confirmed that they stopped practicing with the VR game after less than thirty minutes, reporting that the game was “cool,” however the movement within the game was “disorienting.” If possible, the next iteration of the VR game should address this issue before retesting the equipment.

Seventy percent of participants reported a preference for practicing catheter insertion with the VR game over practice on a manikin and 90% reported the game motivated them to keep practicing. Direct observation and comments made by participants during practice sessions (see Chapter 4) confirm these findings—subjects appeared and/or made comments about engagement, enjoyment, motivation to keep practicing, and losing track of time. Minimal game elements were included in this first iteration consisting of a timer and points accrued for accurately completing the procedure, however students were very competitive, either playing again to beat their own score or the score of their peers.

There were numerous comments from subjects related to the need for more obvious feedback regarding aseptic technique; students reported that the feedback currently offered in the game was too subtle and offered suggestions for how to make it more useful to them (see Chapter 4). Related to this factor, the user reaction survey was split both when asked if it was easy, or conversely, if it was difficult to concentrate on maintaining aseptic technique while practicing using the VR game. Observation of subjects while in the game demonstrated some students’ apparent willingness to sacrifice correct technique in order to better their time; this is concerning since the objective of the game is to practice technique correctly. The feedback factor is an important issue that will need to be addressed and strengthened in the next iteration of the game, perhaps with more specific visual cues (i.e., green *germs* piling up on the sterile field) or the addition of auditory responses.

Question 3: Is there any difference in time spent practicing and/or number of procedures completed in sixty minutes when comparing subjects that practiced with the VR game to those that practiced on a task trainer?

Practice time-on-task for the participants practicing with the VR game was significantly higher than time spent practicing by subjects in the DP control group (p = .001). The number of procedures completed in the VR game group was also significantly higher than for the control group (p < .001). The VR game provides students with individual practice time rather than the traditional method of practicing in pairs with faculty oversight. Student comments and reactions within the game demonstrated the desire to continue to practice whether it was because it was fun or due to the element of competition introduced by points and timer. One of the goals of the developers of this VR game was to provide a method that would allow students the opportunity to practice on their own schedule, at their own pace, deliberately and repetitively, with consistent and accurate feedback. The results and discussion regarding research question two must be considered along with this question—clearly students spent more time practicing, however, some were not necessarily practicing correctly, a factor that leads to discussion of research question four.

Question 4: Is there any difference in ability to demonstrate aseptic technique during urinary catheter insertion two weeks after completing practice sessions when

comparing subjects that practiced with the VR game to those that practiced on a task trainer?

A secondary purpose of this study was to provide an initial analysis of any effect this technology may have on students' ability to demonstrate aseptic technique two weeks post-practice, keeping in mind the sample size is twenty. Both groups demonstrated a pass rate of 60%, a fact that could be interpreted to mean this technology does not work any better than traditional practice. This may also be interpreted to mean that practicing with the VR game is at least as good, and appears to be no worse, than traditional practice. This result could, once again, be connected to the quality of practice previously discussed, i.e. whether or not students are practicing the procedure correctly. The goal is for students to reach the associative or autonomous stage of motor learning; but, if they do not receive accurate, immediate, and consistent feedback on performance, students are just as likely to reach the autonomous stage and complete the procedure incorrectly, something nurse educators need to be ever-mindful of when looking for new teaching strategies. Students found this technology engaging, fun, and motivating, however some of them may not have received the immediate correction they needed in order to successfully and accurately demonstrate the skill. Further and more in-depth analysis of the data is needed to determine if there is a place where mistakes more commonly occurred and whether or not the practice method had any effect on students continuing to make those mistakes.

A serendipitous finding related to this question is the lack of agreement between expert, blinded raters when rating student demonstration video recordings. This apparent subjectivity among faculty raters, even when using an agreed-upon criterion-based checklist, raises concern that requires further investigation.

It is important to note that exploring potential differences in learning between the groups was a secondary purpose of this study. To draw strong conclusions about potential differences in learning would require a larger sample size to adequately detect differences.

Strengths and Limitations of the Study

Strengths

The sample chosen for this study was representative of the target population, undergraduate nursing students, and although small, the sample fit the size criteria for a usability study, the primary focus of this study. A control group with characteristics similar to the treatment group was utilized, making the groups quite comparable at baseline. All participants that started the study also completed all aspects of the study, therefore the attrition was not an issue nor was missing data. The tool used to measure usability, the primary focus in this study has proven itself to be robust and reliable with high face validity (Brooke, 1996). Using a triangulation mixed methods design was chosen in order “to obtain different but complementary data on the same topic” (Morse, 1991, p. 122). Both quantitative and qualitative data were collected from the same participants. Due to the nature of the research questions, most of the study relied on descriptive statistics, however an independent t-test was used appropriately to compare group means and look for significance regarding question number three. The subject matter expert/reviewer for follow-up demonstrations was blinded to any interventions and inter-rater reliability using the criterion-based checklist was assessed.

Limitations

As noted above, exploring the effect of VR on learning was a secondary focus of this study. Nonetheless, the most significant limitation to this study in drawing any conclusions about effect of game play on demonstration of aseptic technique is the small sample size. Data was collected in one baccalaureate nursing program over a very short period of time, one sixty minute practice session. Willingness to participate in the study may have been influenced by students' initial comfort level with technology and video game play. Due to attrition of participants prior to the start of the study, it was difficult to assure similarity of DP control group versus VR game group, most noticeably when comparing semester in the program.

Implications for Nursing Education

The literature agrees that alternatives to traditional apprentice-based approaches to teaching and learning in nursing education are needed. Simulation-based education continues to evolve into a highly interactive and experiential learning strategy that gives nursing students responsibility for their own learning while the educator becomes a facilitator of learning. Simulation combines the cognitive, affective and psychomotor domains of learning in a safe environment where students do not need to worry about hurting patients. Simulation also provides the opportunity for deliberate, repetitive practice of procedural skills. As technology develops and more educational tools become available, nurse educators need to explore the options and find evidence to support strategic implementation of these tools for learning.

This VR game may provide another alternative method for students to practice procedural skills, ultimately, on their own time when it fits into their schedules and without the need for faculty oversight. Increased ability to practice—and perhaps increased motivation to practice with this game—may result in helping students move from the cognitive phase of motor learning into the associative phase and perhaps even to the autonomous phase prior to graduation and transition to practice.

Other procedural skills could be developed in order to create a *library* of skills that students could practice virtually. Ideally, equipment would be hard-wired in a physical game lab of sorts, where students could login, pull up their personal profile, get into the equipment and spend a few minutes practicing when they had time; the system could keep track of hours spent practicing as verification for faculty as well as kept in an e-portfolio for future employers. With current and ongoing emphasis on interprofessional education, multiplayer games could be developed so that players from various professions and in various locations could connect virtually to work together, for example, to run a “Code Blue” patient resuscitation scenario.

We are only beginning to scratch the surface of the possibilities available in education using virtual reality. The findings of this study contribute to the dearth of literature regarding the use of immersive game-based virtual reality for practicing procedural skills in nursing education.

Recommendations for Future Research

Based on the findings and limitations of this study, several recommendations are proposed:

- After further system development based on feedback from this study, the next iteration of the system should be tested with larger numbers, at multiple sites over an extended period of time in order to obtain more powerful data that may then be more generalizable.
- Further and more in-depth research is needed to study the effect of improved feedback in the VR game on students' ability to correctly demonstrate aseptic technique, including whether or not students would remain interested in practicing this way once the novelty of the game wears off.
- Implement intentional learner self-reflection and/or debriefing to ascertain effect on learning and ability to transfer practice from the VR game to patient care.
- Determine if nursing students' preference and comfort with technology or gaming correlates with follow-up demonstration performance to see if preferences have any effect on outcomes.
- Explore return on investment of VR game equipment either in addition to, or in place of, other simulation equipment as well as related to supply usage and faculty time.
- Examine retention and ability to transfer skills practiced with the VR game to patient care and determine effect on patient outcomes including patient safety.
- Further study is needed to address issues of faculty subjectivity in rating students' ability to demonstrate skill competence using criterion-based checklists.

- Explore the learning that may occur during observation of game-playing, similar to the learning that has been shown to occur while students fulfill the role of observers in simulation scenarios.

Conclusion

This study adds to limited research in nursing education related to procedural skill development of undergraduate nursing students by exploring the use of a unique game-based virtual reality system for practicing procedural skills. This innovative game-based virtual reality system was very well-received by participants in this study. The usability ratings demonstrated student willingness and, in most cases, eagerness to use this tool for learning. Observation and the user reaction survey results revealed students that were excited and motivated to practice this skill virtually. They were engaged in their own learning and many were clearly enjoying the experience. All participants found the system quite easy to use although they also reported feeling they would need tech support to be successful with the system. Most students were comfortable in the headgear for nearly an hour although two subjects asked to stop play after less than thirty minutes due to complaints of dizziness or headache. Similar to any learning strategy, this VR game is not ideal for everyone but it may be helpful for some students. The results of this study indicate students that practiced with the VR game practiced significantly longer and completed a significantly higher number of procedures in sixty minutes, however the pass rate on return demonstration two weeks after practice sessions was equal for both groups at just 60%. The findings from this study support the need for continued research in the area of developing technology and related pedagogy to help undergraduate nursing students develop procedural skills.

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APPENDIX A

Urinary Catheter Insertion Criterion-Based Checklist

Steps	Met	Not Met	Comments
***1. Follow standard protocol (knock, wash hands, ID self and ID patient)**			
2. Properly position patient, drape patient as appropriate. Position lighting to best visualize anatomy.			
***3. Open prepackaged catheter kit on bedside table without reaching over sterile field (back flap first, sides next, front flap open last and towards student).**			
4. Place sterile waterproof drape under client's buttocks (for females) without contaminating the center of the drape.			
***5. Apply sterile gloves and maintain sterile field at all times.** **(Rater: If sterile field broken, please comment at which point in procedure)**			
6. Leave kit on bedside table during preparation and insertion. Prepare all kit materials: • Open the antiseptic swabs. • Open manikin lubricant. • Remove wrapper, lubricate the catheter 1"-2" for females and place inside the sterile container.			
***7. Separate labia with non-dominant hand. This hand becomes unsterile.**			
***8. With the sterile hand cleanse the meatus performing one downward stroke with each swabstick and discarding without breaking sterile field.**			
9. Continue to hold the labia with non-dominant hand.			
***10. Gently insert catheter. As soon as you have urine flow advance catheter 2 inches further.**			
***11. Hold the catheter with non-dominant hand and inflate balloon with the designated volume with dominant hand. Do not let go of catheter until balloon is inflated. Pull gently on catheter until resistance is met.**			
12. Secure catheter with catheter-securing device.			
***13. Place bedside collection bag lower than bladder and position so there are no dependent loops (this step will be verbalized).**			

APPENDIX B

Institutional Review Board Approval (with Modification Approval)

BOISE STATE UNIVERSITY
RESEARCH AND ECONOMIC DEVELOPMENT

Date: February 24, 2015

To: Ann Butt cc: Keith Thiede

From: Social & Behavioral Insitutional Review Board (SB-IRB)
c/o Office of Research Compliance (ORC)

Subject: SB-IRB Notification of Approval - Original - 187-SB15-034
Using Simulation for Development of Procedural Skills in Undergraduate Nursing Students

The Boise State University IRB has approved your protocol submission. Your protocol is in compliance with this institution's Federal Wide Assurance (#0000097) and the DHHS Regulations for the Protection of Human Subjects (45 CFR 46).

Protocol Number:	**187-SB15-034**	Received:	2/17/2015	Review:	Expedited
Expires:	**2/23/2016**	Approved:	2/24/2015	Category:	6, 7

Your approved protocol is effective until 2/23/2016. To remain open, your protocol must be renewed on an annual basis and cannot be renewed beyond 2/23/2018. For the activities to continue beyond 2/23/2018, a new protocol application must be submitted.

ORC will notify you of the protocol's upcoming expiration roughly 30 days prior to 2/23/2016. You, as the PI, have the primary responsibility to ensure any forms are submitted in a timely manner for the approved activities to continue. If the protocol is not renewed before 2/23/2016, the protocol will be closed. If you wish to continue the activities after the protocol is closed, you must submit a new protocol application for SB-IRB review and approval.

You must notify the SB-IRB of any additions or changes to your approved protocol using a Modification Form. The SB-IRB must review and approve the modifications before they can begin. When your activities are complete or discontinued, please submit a Final Report. An executive summary or other documents with the results of the research may be included.

All forms are available on the ORC website at http://goo.gl/D2FYTV

Please direct any questions or concerns to ORC at 426-5401 or humansubjects@boisestate.edu.

Thank you and good luck with your research.

Mary E. Pritchard

Dr. Mary Pritchard
Chair
Boise State University Social & Behavioral Insitutional Review Board

1910 University Drive Boise, Idaho 83725-1139
Phone (208) 426-5401 orc@boisestate.edu

This letter is an electronic communication from Boise State University

BOISE STATE UNIVERSITY
RESEARCH AND ECONOMIC DEVELOPMENT

Date: March 16, 2015

To: Ann Butt cc: Keith Thiede

From: Social & Behavioral Insitutional Review Board (SB-IRB)
c/o Office of Research Compliance (ORC)

Subject: SB-IRB Notification of Approval - Modification - 187-SB15-034
Using Simulation for Development of Procedural Skills in Undergraduate Nursing Students

The Boise State University IRB has approved your proposed modifications to your protocol application. Your protocol is still in compliance with this institution's Federal Wide Assurance (#0000097) and the DHHS Regulations for the Protection of Human Subjects (45 CFR 46).

Protocol Number:	**187-SB15-034**	Received:	3/12/2015	Review:	Expedited
Expires:	**2/23/2016**	Approved:	3/16/2015		

This approval does not extend or change your protocol's current expiration date noted above.

You must notify the SB-IRB of any additional changes to your approved protocol using a Modification Form. The SB-IRB must review and approve the modifications before they can begin.

All forms are available on the ORC website at http://goo.gl/D2FYTV

Please direct any questions or concerns to ORC at 426-5401 or humansubjects@boisestate.edu.

Thank you and good luck with your research.

Mary E. Pritchard

Dr. Mary Pritchard
Chair, Social & Behavioral Insitutional Review Board

APPENDIX C

Boise State University College of Health Sciences Simulation Center Waiver

Boise State University College of Health Sciences Simulation Center Waiver

As a participant in a simulated patient care environment at Boise State University, College of Health Sciences Simulation Center and School of Nursing, I understand I will be both an active participant in realistic scenarios and an observer of others immersed in similar situations. I understand that participating in simulation-based training is part of my clinical learning experience. I will engage in and participate in the simulation fully as a professional and treat it as a realistic patient care experience (the "Participation").

Confidentiality of Information

I understand that the content of these simulations is to be kept confidential to maintain the integrity of the learning experience for myself and fellow students. I also understand that in working collaboratively during simulation scenarios, I will be witnessing others' performances and I recognize that it would be unethical for me to share information regarding student performance with persons outside of this setting. I will, at all times during my Participation and for a period of five (5) years thereafter, maintain and keep confidential all Confidential Information. "Confidential Information" is defined as anything that I, or those individuals with whom I interact, would expect to remain private including information relating to the performance of other individuals, the details of the simulation scenarios and educational activities conducted, whether seen in real time, on video, or otherwise communicated to me, and any discussions related thereto. Confidential Information may only be used as needed to perform my assigned activities.

Digital Video/Audio Release Form

I understand that Boise State University may record/photograph me in still, digital, film or video formats or any combination thereof during simulation and educational activities. I hereby grant and assign to Boise State University the rights, including moral rights, of my image, likeness, and sound of my voice as recorded on audio or video tape during my Participation without payment or any other consideration.

I consent that all such produced and/or derived material may be distributed and/or circulated by Boise State University wherever and to whomever they may deem necessary or desirable for any general or specific educational uses.

I understand that my image may be edited, copied, exhibited, published or distributed and waive the right to inspect or approve the finished product wherein my likeness appears. Further, I hereby waive any right to any royalties or other compensation arising from or related to the use of my image or recording, and I release Boise State University, its directors, officers, employees, agents, and students from and against any claim for injury or compensation resulting from the activities authorized by this agreement.

Recordings/photographs in still, digital, film or video formats or any combination thereof may also be used for research purposes if the research has been approved by the University Institutional Review Board.

If I am part of an outside entity using Boise State University's Simulation Center, I understand Boise State University may release recordings/photographs in still, digital, film or video formats or any combination thereof to the outside entity for educational, non-commercial purposes upon request. Those copies may not be further distributed without the prior written consent of Boise State University.

Observers

The College of Health Sciences Simulation Center and School of Nursing may share its experiences and expertise with those who occasionally visit to observe the educational, administrative, and technical aspects of learning. During observations by these individuals, neither students nor faculty are identified by name, nor are individual student evaluations shared. I understand that there may be individuals observing as I participate in simulation and educational activities and I consent to their presence.

By signing below, I acknowledge to having completely read, fully understand the above statements and agree to be bound thereby. I understand that this consent is applicable to all simulation and educational activities at Boise State University that I may take part in from this point forward.

Print Name: ________________________________ Date: ____________________________

Signature: ______________________________

APPENDIX D

Study Recruitment Script

Using Simulation for Development of Procedural Skills in Undergraduate Nursing Students

Ann Butt, Principal Investigator with Dr. Keith Thiede, Co-PI/Graduate Advisor

My name is Ann Butt and I am a graduate student researcher at Boise State University, working on a doctorate in education. I am conducting a research study about how to help undergraduate nursing students practice procedural skills using simulation; this study will focus on demonstration of aseptic technique during urinary catheter insertion. I am looking for twenty students that are willing to participate in this important study, both students that are confident in their ability to maintain aseptic technique throughout the procedure as well as those of you that feel you could use more practice.

If you decide to participate, the study will require approximately two hours of your time over the first three weeks of March. After completing a 15 minute survey today, you will be randomly assigned to one of two groups. One group will be given one hour during the first week of March to practice using a task trainer with feedback from faculty (similar to DRP). The other group will practice catheter insertion individually using innovative simulation technology with immediate feedback and complete a brief survey about the experience. Approximately two weeks after practicing, all participants will be asked to return to the Sim Center to demonstrate urinary catheter insertion.

Both the practice session and the demonstration of catheter insertion will be digitally recorded in the Simulation Center for review by the research team. Obviously, anonymity cannot be guaranteed, however all information will be protected and only the research team will have access to the video recordings. In addition to the video release form you have already signed related to learning in the Simulation Center, you will be asked to sign a separate consent to video record for this study. These recordings will be reviewed by members of the research team and then erased. All study participants will receive an identification code at the start of the study; names will not be used in data collection or in the analysis or reporting of data.

You may withdraw from the study at any time without penalty and your participation or lack of participation in the study will not influence your grades. Individual information from the study will not be shared with any of your faculty or administration in the School of Nursing.

The benefits to you are that you will have a chance to practice catheter insertion with feedback on your performance; depending on which group you are assigned to, you may have the opportunity to try out and share your opinions about an innovative method designed to help students practice procedural skills. Patients will ultimately benefit from having more experienced, educated, skilled, and confident student nurses caring for them. The main benefits to you and society are that findings from this study will contribute to an understanding of how best to learn with simulation. Improved teaching techniques may enable healthcare providers to retain their procedural skill proficiency, preparing them to perform when needed in a competent and confident manner.

- Need to be able to schedule one hour on Wednesday, March 4th between 8am and 6pm OR Friday morning, March 6th between 8 and 10am. There may also be hours on Tuesday, March 3rd between 10am and noon.
- Follow up demonstration will be scheduled for Monday or Tuesday, March 16th or 17th for approximately 15 minutes.

APPENDIX E

Informed Consent

Study Title: Using Simulation for Development of Procedural Skills in Undergraduate Nursing Students

Principal Investigator: Ann Butt **Co-Investigator:** Dr. Keith Thiede

- **PURPOSE AND BACKGROUND**

  The purpose of this research is to explore the use of new simulation technology for practicing procedural nursing skills, in this case, inserting a urinary catheter using aseptic technique.

- **PROCEDURES**

  If you agree to be in this study, you will participate in a brief survey, a one hour practice session and a 15 minute follow-up appointment to demonstrate catheter insertion.

- **RISKS**

  In the unlikely event that some of the survey questions or the intervention activity make you uncomfortable or upset, you are always free to decline to answer or to stop your participation in the practice session at any time. The study will be digitally recorded—both the practice session and the follow-up skill demonstration—and you may be identifiable by your videos. These recordings and/or any still shots may be used for future presentations and/or publications. Your demonstration of catheter insertion will be video recorded and analyzed using the catheter insertion check sheets, identified by study ID numbers only.

- **QUESTIONS:** If you have any questions or concerns about your participation in this study, you may contact the Principal Investigator, Ann Butt at 208-426-4202 or annbutt@boisestate.edu or the co-investigator Dr. Keith Thiede at 208-426-1278 or keiththiede@boisestate.edu.

  If you have questions about your rights as a research participant, you may contact the Boise State University Institutional Review Board (IRB), which is concerned with the protection of volunteers in research projects. You may reach the board office between 8:00 AM and 5:00 PM, Monday through Friday, by calling (208) 426-5401 or by writing: Institutional Review Board, Office of Research Compliance, Boise State University, 1910 University Dr., Boise, ID 83725-1138.

DOCUMENTATION OF CONSENT

I have read this form and decided that I will participate in the project described above. Its general purposes, the particulars of involvement and possible risks have been explained to my satisfaction. I understand I can withdraw at any time.

Printed Name of Study Participant	**Signature** of Study Participant	Date

APPENDIX F

System Usability Survey

System Usability Survey

Please check the circle that reflects your immediate response to each statement. Don't think too long about each statement but please make sure your respond to every statement. If you're not sure, simply check "Neither Agree nor Disagree."

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

I think I would like to use this simulation frequently.

O	O	O	O	O

I found the simulation unnecessarily complex.

O	O	O	O	O

I thought the simulation was easy to use.

O	O	O	O	O

I think that I would need the support of a technical person to be able to use this sim.

O	O	O	O	O

I found the various functions in this sim were well integrated.

O	O	O	O	O

I thought there was too much inconsistency in this simulation.

O	O	O	O	O

I would imagine that most people would learn to use this sim very quickly.

O	O	O	O	O

I found the simulation very awkward to use.

O	O	O	O	O

I felt very confident using the simulation.

O	O	O	O	O

I needed to learn a lot of things before I could get going with this simulation.

○ ○ ○ ○ ○

Please give your overall rating of the user-friendliness of this virtual simulation technology:

Worst Imaginable	Awful	Poor	OK	Good	Excellent	Best Imaginable
○	○	○	○	○	○	○

APPENDIX G

User Reaction Survey

User Reaction Survey

Please consider your experience with the virtual reality catheter insertion game and respond to the statements using this scale:

Highly Disagree	Disagree	Agree	Highly Agree

At times during the hour, I felt totally absorbed in practicing.

O	O	O	O

I did not find any challenge within this game.

O	O	O	O

Practicing this way was fun.

O	O	O	O

I felt engaged in my own learning while practicing.

O	O	O	O

I found it difficult to concentrate on maintaining aseptic technique while practicing this way.

O	O	O	O

Using this technology motivated me to keep practicing.

O	O	O	O

Practicing this way was boring.

O	O	O	O

I lost track of time while practicing.

O	O	O	O

Practicing this way was not engaging.

O	O	O	O

There were elements of challenge within the game.

O	O	O	O

I would be more likely to practice cath insertion using this game than a task trainer.

O O O O

I found practicing this way frustrating.

O O O O

It was easy to concentrate on maintaining aseptic technique using this game.

O O O O

At no time was I absorbed in the game while practicing.

O O O O

I found my way around the game easily.

O O O O

The headgear was uncomfortable.

O O O O

I would rather practice on a task trainer with faculty providing feedback.

O O O O

I found myself wondering when my hour was up and I could be finished.

O O O O

Wearing the headgear did not bother me.

O O O O

I did not enjoy practicing this way.

O O O O

Practicing this way was physically uncomfortable i.e. tiring, made me dizzy and/or nauseous.

O O O O

I got the feedback I needed, when I needed it.

O O O O

I worked to improve my score during my practice time.

O O O O

Overall, how was your experience practicing procedural skills this way compared to on a manikin? Please consider motivation, engagement and quality of practice.

Please share any suggestions that you feel would improve your learning experience with this game:

Practicing this way will help me insert a catheter correctly.

Highly Disagree	Disagree	Agree	Highly Agree
O	O	O	O

APPENDIX H

Study Participant Initial Survey

Study Participant Initial Survey

Name: ______________________________ Email: _____________________________

Semester in Nursing Program: ___________ Gender: _________

Ethnicity: ___________ Overall GPA: __________

Year you graduated from high school: ___________ Age: __________

Do you own a smartphone? (please circle) Yes/No

Do you use Twitter? Yes/No Facebook? Yes/No Instagram? Yes/No

How many hours a week do you spend playing computer games on-line? _________

How many hours/week do you spend playing console-based games? __________

If you didn't have to study, how many hours/week would you spend playing computer games? _______

Do you consider yourself a gamer? Yes/No

If so, what kind of games do you prefer? _______________________________________

How comfortable are you with technology in general? (circle)

Very comfortable OK Not at all comfortable

How do you feel about simulation for learning? Circle and write brief response if you can explain.

Love it, really helps me learn Why?____

Take it or leave it Why? ____

Really don't like it Why not? ______________________________________

For catheter insertion, are you: Right-handed only Left-handed only Ambidextrous (circle answer)

APPENDIX I

System Usability Survey Individual Item Frequencies

System Usability Survey Individual Item Frequencies

I would like to use this system frequently

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	1	10.0	10.0	10.0
	Neutral	1	10.0	10.0	20.0
	Agree	4	40.0	40.0	60.0
	Highly Agree	4	40.0	40.0	100.0
	Total	10	100.0	100.0	

I found the sim unnecessarily complex

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Highly Disagree	3	30.0	30.0	30.0
	Disagree	6	60.0	60.0	90.0
	Neutral	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

I thought the sim was easy to use

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	1	10.0	10.0	10.0
	Agree	6	60.0	60.0	70.0
	Highly Agree	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

I would need support of tech person to use sim

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Highly Disagree	1	10.0	10.0	10.0
	Disagree	1	10.0	10.0	20.0
	Neutral	1	10.0	10.0	30.0
	Agree	4	40.0	40.0	70.0
	Highly Agree	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

I found various functions of sim well integrated

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Agree	6	60.0	60.0	60.0
	Highly Agree	4	40.0	40.0	100.0
	Total	10	100.0	100.0	

I thought there was too much inconsistency

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Highly Disagree	3	30.0	30.0	30.0
	Disagree	5	50.0	50.0	80.0
	Neutral	1	10.0	10.0	90.0
	Highly Agree	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

I would imagine most people would learn to use this sim quickly

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	1	10.0	10.0	10.0
	Neutral	2	20.0	20.0	30.0
	Agree	5	50.0	50.0	80.0
	Highly Agree	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

I found the sim very awkward to use

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Highly Disagree	4	40.0	40.0	40.0
	Disagree	5	50.0	50.0	90.0
	Agree	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

I felt very confident using the simulation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	1	10.0	10.0	10.0
	Neutral	1	10.0	10.0	20.0
	Agree	4	40.0	40.0	60.0
	Highly Agree	4	40.0	40.0	100.0
	Total	10	100.0	100.0	

I needed to learn a lot of things before I could get going

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Highly Disagree	3	30.0	30.0	30.0
	Disagree	4	40.0	40.0	70.0
	Neutral	1	10.0	10.0	80.0
	Agree	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

Overall rating of virtual simulation technology

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Poor	1	10.0	10.0	10.0
	Good	2	20.0	20.0	30.0
	Excellent	6	60.0	60.0	90.0
	Best imaginable	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

APPENDIX J

User Reaction Survey Individual Item Frequencies

User Reaction Survey Individual Item Frequencies

At times during the hour, I felt totally absorbed in practicing.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	2	20.0	20.0	20.0
	Agree	2	20.0	20.0	40.0
	Strongly Agree	6	60.0	60.0	100.0
	Total	10	100.0	100.0	

I did not find any challenge within this game.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	2	20.0	20.0	20.0
	Disagree	4	40.0	40.0	60.0
	Agree	2	20.0	20.0	80.0
	Strongly Agree	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

Practicing this way was fun.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Agree	4	20.0	40.0	40.0
	Strongly Agree	6	30.0	60.0	100.0
	Total	10	100.0	100.0	

I felt engaged in my own learning while practicing

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Agree	4	40.0	40.0	40.0
	Strongly Agree	6	60.0	60.0	100.0
	Total	10	100.0	100.0	

I found it difficult to concentrate on maintaining aseptic technique

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	1	10.0	10.0	10.0
	Disagree	4	40.0	40.0	50.0
	Agree	5	50.0	50.0	100.0
	Total	10	100.0	100.0	

Using this technology motivated me to keep practicing.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	1	10.0	10.0	10.0
	Agree	3	30.0	30.0	40.0
	Strongly Agree	6	60.0	60.0	100.0
	Total	10	100.0	100.0	

Practicing this way was boring.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	8	80.0	80.0	80.0
	Disagree	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

I lost track of time while practicing.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Agree	6	60.0	60.0	60.0
	Strongly Agree	4	40.0	40.0	100.0
	Total	10	100.0	100.0	

Practicing this way was not engaging.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	9	90.0	90.0	90.0
	Disagree	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

There were elements of challenge within the game.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Agree	8	80.0	80.0	80.0
	Strongly Agree	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

I would be more likely to practice cath insertion using this game than a task trainer

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	3	30.0	30.0	30.0
	Agree	6	60.0	60.0	90.0
	Strongly Disagree	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

I found practicing this way frustrating.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	3	30.0	30.0	30.0
	Disagree	5	50.0	50.0	80.0
	Agree	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

It was easy to concentrate on maintaining aseptic technique using this game.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	5	50.0	50.0	50.0
	Agree	4	40.0	40.0	90.0
	Strongly Agree	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

At no time was I absorbed in the game while practicing.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	3	30.0	30.0	30.0
	Disagree	6	60.0	60.0	90.0
	Agree	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

I found my way around the game easily.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	1	10.0	10.0	10.0
	Agree	4	40.0	40.0	50.0
	Strongly Agree	5	50.0	50.0	100.0
	Total	10	100.0	100.0	

The headgear was uncomfortable.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	5	50.0	50.0	50.0
	Disagree	5	50.0	50.0	100.0
	Total	10	100.0	100.0	

I would rather practice on a task trainer with faculty providing feedback.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	6	60.0	60.0	60.0
	Agree	4	40.0	40.0	100.0
	Total	10	100.0	100.0	

I found myself wondering when my hour was up and I could be finished.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	5	50.0	50.0	50.0
	Disagree	3	30.0	30.0	80.0
	Agree	1	10.0	10.0	90.0
	Strongly Agree	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Wearing the headgear did not bother me.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Agree	4	40.0	40.0	40.0
	Strongly Agree	6	60.0	60.0	100.0
	Total	10	100.0	100.0	

I did not enjoy practicing this way.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	6	60.0	60.0	60.0
	Disagree	3	30.0	30.0	90.0
	Strongly Agree	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Practicing this way was physically uncomfortable i.e. tiring, made me dizzy and/or nauseous.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	5	50.0	50.0	50.0
	Disagree	3	30.0	30.0	80.0
	Agree	1	10.0	10.0	90.0
	Strongly Agree	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

I got the feedback I needed, when I needed it.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Agree	6	60.0	60.0	60.0
	Strongly Agree	4	40.0	40.0	100.0
	Total	10	100.0	100.0	

I worked to improve my score during my practice time.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	2	20.0	20.0	20.0
	Agree	1	10.0	10.0	30.0
	Strongly Agree	7	70.0	70.0	100.0
	Total	10	100.0	100.0	

Practicing this way will help me insert a catheter correctly.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Agree	7	70.0	70.0	70.0
	Strongly Agree	3	30.0	30.0	100.0
	Total	10	100.0	100.0	