THE IMPACT OF VIRTUAL RADIOGRAPHIC POSITIONING SIMULATION ON 1ST YEAR RADIOGRAPHY STUDENTS' CLINICAL PREPAREDNESS THROUGH THE LENS OF ACTIVITY THEORY: A MIXED METHOD APPROACH

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DEDICATION

This dissertation is dedicated to my best friend and biggest supporter, my wife Janelle, who has never doubted me, even when I did. You are my favorite person. I would also like to dedicate this dissertation to my children Ryan, Olivia, Emily, and Amy. Their love gave me the strength to finish this project. Hopefully someday it inspires them to achieve their biggest goals.

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ABSTRACT

Radiography education programs are designed to prepare students to perform radiographic examinations and acquire diagnostic medical images of real patients in the clinical setting. Radiographic Science (RS) education, like all healthcare education, is uniquely different from education in other professional fields. Students must not only acquire the technical, cognitive learning required, but they must also master the psychomotor skills necessary to apply didactic knowledge to patients in a clinical setting. In medical imaging, when students are hesitant or lack knowledge and skills they are prone to produce images with decreased quality or expose patients to unnecessarily high amounts of radiation. RS educational programs should establish a way to improve students' competence in terms of radiographic examinations as part of preparing students (i.e. self-efficacy and positioning skills) to enter a clinical setting.

Research suggests simulation helps develop competence in RS students prior to demonstrating that competence on real patients in the clinical setting. Simulations, aka real life simulated learning scenarios, use mannequins, phantoms, and/or people to practice radiographic positioning. Virtual simulation is a new educational tool which has the potential to help supplement deficiencies in traditional simulation. Virtual simulation uses technology enhanced simulation through the medium of a computer software program. Leveraging all the benefits of traditional simulation, virtual simulation decreases the demands for time, space, and equipment as compared to traditional simulation and has the added benefits of "anytime, anywhere" flexibility, scalability, scaffolding, and presenting unique or unusual scenarios to students. Many studies evaluating the use of virtual simulation have been performed in various medical education disciplines; however, little empirical research has been performed in the field of RS education.

The purpose of this study was to investigate first year radiography students' perceptions of their own self-efficacy and clinical skills after using a virtual radiography simulation in an undergraduate radiography course. A mixed-methods research design was used following an explanatory sequential research model to investigate students' perceptions of their own self-efficacy and positioning skills after using the virtual radiographic positioning simulation software program MedspaceXR. Students' self-efficacy and clinical skills were based on the perceptions of students evaluated through a survey instrument and follow-up interviews built on the tenets of Activity Theory (AT). Students were given access to the virtual simulation program to use on their own in addition to their normal didactic coursework. Participants included first year radiography students in one cohort of a RS education program in the intermountain West; 13 students responded to the survey, and 8 students were selected for interviews.

The findings for this study have many implications for both radiographic science educators and for radiographic science students. While no simulation or education can fully replace actual experience, the results of this study showed students benefit from practice in a safe and risk free environment before performing exams on real patients. When implementing a virtual simulation program educators should help mitigate the negative effects of using a new technology program by providing adequate direction and instruction to students. Educators should also find ways to help students "buy in" to using

a virtual simulation program, as research results showed students self-efficacy and positioning skills increased the more they used the simulation program. This study indicates students felt the virtual simulation was a good addition to, but should not be a replacement for, traditional laboratory positioning practice. The conclusions drawn from this research can help provide educators a base of information on how students perceive their own clinical readiness after using a virtual simulation program and can guide further research studies of virtual simulation in health care education.

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LIST OF ABBREVIATIONS

ACR	American College of Radiology
ARRT	American Registry of Radiologic Technologists
AT	Activity Theory
CBL	Case-Based Learning
CBR	Case-Based Reasoning
CFT	Cognitive Flexibility Theory
CI	Clinical Instructor
CL	Collaborative Learning
CPR	Cardiopulmonary Resuscitation
CT	Computed Tomography
DICOM	Digital Imaging and Communications in Medicine
ESR	Explanatory Sequential Research
JRCERT	Joint Review Committee on Education in Radiologic Technology
MMR	Mixed Methods Research
MRI	Magnetic Resonance Imaging
PACS	Picture Archival and Communication System
PET	Positron Emission Tomography
RQ1	Research Question 1
RQ2	Research Question 2
RS	Radiographic Science

SID	Source-to-Image Receptor Distance
SLT	Social Learning Theory
STO	Student – Tool – Outcome

CHAPTER ONE: INTRODUCTION

The goal of radiography education programs is to prepare students to be clinically competent in the classroom and laboratory setting before demonstrating that competence on real patients in the clinical setting. Radiographic science (RS) educational programs should establish a way to improve students' competence in terms of radiographic examinations as part of preparing students (i.e. competence, comfort, and confidence) to enter a clinical setting. Though educational curriculum is established by the American Registry of Radiologic Technologists (ARRT) and educational accreditation requirements are established by the Joint Review Committee on Education in Radiologic Technology (JRCERT), it is up to each RS program to implement educational practices effectively within the facility and time constraints of the individual program.

By the end of the educational program students must demonstrate competence in performing all required radiographic examinations in a safe and proficient manner. When students start the RS program, they have no previous experience and are often hesitant or unsure when working with patients. In medical imaging, when students are hesitant or lack knowledge and skills they are prone to produce images with decreased quality or expose patients to unnecessarily high amounts of radiation (Ortiz, 2015). New RS students also tend to take a much longer time to perform the exams than when they are more familiar and comfortable with their knowledge and skills. Comfort, familiarity, and skills are acquired with time and practice, but these are experiences new RS students do not have. Research suggests RS students benefit from the opportunity to practice radiographic examinations in a simulated environment prior to demonstrating that competence on real patients in the clinical setting (Holmström & Ahonen, 2016; Marshall & Harris, 2000; Sedden & Clark, 2016; Shanahan, 2016a). However, educational program facilities which provide students opportunity to practice radiographic examinations in a simulated environment are often limited, both in terms of quantity (i.e. number of simulation rooms and equipment available) and availability (i.e. laboratory time for practice throughout the semester).

To prepare students for the clinical setting, radiography educators must find ways to develop student clinical competence. Since educational time and equipment resources in the RS program are limited, new methods of helping students develop clinical competence must be developed. Research must be performed to evaluate the most pedagogically and cost effective techniques to help increase student clinical competence.

As noted, research suggests simulation helps develop competence in RS students prior to demonstrating that competence on real patients in the clinical setting. This research project investigated the implementation of a virtual radiographic positioning simulation software program into pre-established RS curriculum. The intervention did not replace any current pedagogical techniques, practices, or instruction. Instead it gave students additional opportunity to practice radiographic positioning in a virtual environment outside of established classroom and laboratory time. Students then completed a survey instrument to ascertain their own competence and self-efficacy after using the virtual simulation program. Those students with the highest and lowest survey instrument scores then participated in individual interviews to further analyze how the virtual simulation program impacted their competence and self-efficacy.

Background of Radiographic Science Education

On November 8, 1895 Wilhelm Conrad Roentgen discovered a new form of radiation completely by accident. He called this radiation “X-ray”, “x” being the mathematical symbol for the unknown. Through intense study over the period of a few weeks, Roentgen published his findings to the Würzburg Physico-Medical Society, his local professional society. His article, “On a New Kind of Rays”, outlined 14 characteristics of X-rays. Since that time, no other properties of X-rays have been discovered (Fauber, 2013). The scientific understanding of the nature and properties of X-rays has not changed since 1895. The same cannot be said for the application and biological effects of X-rays; this type of radiation is continuously being investigated. Shortly after their discovery, X-rays were quickly adapted to medical use. Physicians embraced the ability to see inside the body without cutting patients open. Doctors started purchasing their own X-ray producing machines, but soon learned they had to focus their time on the interpretation of the X-ray images instead of their acquisition and formation. As the novelty of creating X-ray images wore off, more scrutiny was placed the physician’s ability to make diagnoses from the X-ray images (Harris, 1995). In taking more time interpreting the radiographs, the doctor had less time to spend learning how to use the X-ray equipment and produce the images.

From this disparity, a new medical field was born: radiographic science. Radiographic science is the study of how to acquire an X-ray image and includes knowledge about how x-radiation is produced, how the radiation interacts with living tissue, how images are created, how the machine operates, and what the proper positioning techniques are used to produce the highest quality X-ray image possible

(Tolley Gurley & Callaway, 2011). In modern terms, medical doctors who specialize in the interpretation and diagnosis of X-ray images are known as *radiologists*; those who specialize in how to produce X-rays and acquire quality diagnostic images are known as *radiographers*, *radiologic technologists*, or *X-ray techs*.

In the early 1900s there was no formal training for radiographers. Most were medical office assistants who were trained by a doctor on how to “take” an X-ray. These people often had no medical background or understanding of anatomy (Harrison, 1984). Sometimes doctors would use nurses, when they were available, to make X-rays because at least they had some medical training and knowledge of anatomy. As the use of X-rays in medicine proliferated, there became a need to train competent X-ray techs. Training for these techs followed the apprentice model: see one, do one, teach one. Then, once the doctor or radiologist was convinced the tech was “reasonably competent in the mechanical aspects, they were often left to experiment on their own” (Harris, 1995, p. 21). Techs used the “hunch method” by taking X-rays by what felt right. There was no standardization of radiation exposure, positioning technique, or X-ray film development. Seeking to fill this educational void, Eddy Jerman published his book “Modern X-ray Technic” in 1928. Jerman is often referred to as the father of RS for his outstanding achievements in the field of X-ray and for being the first to establish standards and techniques (Milligan, 1976). He was also instrumental in the movement to push for standards in the education and training of radiographers.

Initially, as was stated, training for radiographers came though observation and practice in the clinical setting. No formal training or education was required. However, events in the first half 20th Century, including World War I and World War II, exacerbated the need to have radiographers who were competent, educated, and trained prior to entering the clinical setting (Harris, 1995). Formal radiography training programs were established, primarily in hospital radiology departments, but also as certificate programs at universities. In the second half of the 20th Century, the impetus for establishing professionalism and a professional field lead higher education institutions to develop degree programs in RS (Harrison, 1984). Education had moved from the apprentice model to a formal educational degree, and with it the adaptation of formal educational practices and theories to RS education.

Radiographic Science Education Today

Radiographic Science (RS) education, like all healthcare education, is uniquely different from education in other professional fields. While education for other professional fields (e.g. engineering, history, English, education, biology, etc.) focus solely on didactic or schoolwork learning, healthcare education is dually split between didactic and clinical education (Densen, 2011; Scheckel, 2009). Students must not only acquire the technical, cognitive learning required, but they must also master the psychomotor skills necessary to apply didactic knowledge to patients in a clinical setting. Before working with patients in the clinical setting, students develop learning and skills through supervised practice in a laboratory setting (aka simulation). Simulation has been found to be the most common educational tool used to train and prepare students in healthcare (Motola, Devine, Chung, Sullivan, & Issenberg, 2013; Shanahan, 2016a). Recently, the use of simulation has increased across the healthcare education continuum in such areas as patient safety, acquiring and honing clinical skills in a controlled environment, and promotion of individual and group learning (Monachino & Tuttle, 2015; Motola et al. 2013). In RS education, chief among these trends is to improve psychomotor performance when preparing students to learn and practice in a clinical setting.

Purpose of the Study

The purpose of this study was to investigate students' perceptions of their own self-efficacy and positioning skills after using a virtual radiography simulation in an undergraduate course. Self-efficacy and clinical skills were based on the perceptions of student evaluated through a survey instrument and follow-up interviews built on the tenets of Activity Theory (AT).

Simulation (both live and virtual) has been identified as the most common method of helping students prepare to perform radiographic examinations on real patients in hospitals and clinics (Motola et al., 2013; Shanahan, 2016a). Real-life simulation (aka simulation) in radiographic education is the use of high-fidelity mannequins or real life people for the practice of radiographic positioning (Ahlqvist et al., 2013; Berry et al., 2007; Cook et al., 2012; Gordon, Oriol, & Cooper, 2004; Kasprzak, 2016; Kong, Hodgson, & Druva, 2015; Wright et al., 2006). Virtual simulation is defined as technology-enhanced simulation for the same purpose as real-life simulation but performed through the medium of a computer software program (Issenberg & Scalese, 2008; Kasprazak, 2016, Shanahan, 2016a).

Several virtual simulation software products are available commercially. This research project focused on the effect the virtual radiographic positioning simulation software (MedspaceXR) had on student self-reported self-efficacy and positioning skills. Studying student perceptions of implementing virtual simulation in radiographic education curriculum will help the RS programs understand the role virtual simulation has on student self-efficacy and positioning skills. Since all RS educators struggle with preparing students to be clinically competent, this understanding can then be used to help other radiography programs more effectively increase student perceptions of their competence through the use of virtual simulation.

Research Questions

The goal of radiographic science education programs is to prepare students to perform radiographic examinations on real patients in hospitals and clinics. Currently there is a paucity of literature available on preparing students to enter the clinical setting as it directly relates to RS. Though little information was found, literature reviews conducted by other researchers about the preparedness of RS students found common pedagogical themes including active learning, motivation, case-based studies, reflection, situations which require critical-thinking skills, objective structured clinical examination, and engagement activities (Holmström & Ahonen, 2016; Marshall & Harris, 2000; Sedden & Clark, 2016). However, the most common theme among the articles reviewed was the use of simulation. These articles touted the benefits of simulation for RS students but cited little empirical evidence of their implementation. The research mainly pointed to the use of simulation in other allied health professions and advocated the implementation of such techniques in RS education. Research suggests RS students benefit from the opportunity to practice radiographic examinations in a simulated environment prior to demonstrating that competence on real patients in the clinical setting (Holmström & Ahonen, 2016; Marshall & Harris, 2000; Sedden & Clark, 2016; Shanahan, 2016a).

To investigate students’ perceptions of their own self-efficacy and positioning skills after using a virtual radiography simulation, the following research questions were developed. They were further explored in phases of analysis follow a mixed-methods explanatory sequential research (ESR) design, with Phase 1 being quantitative, and Phase 2 being qualitative. Answering these research questions will help address the problem of RS student clinical preparedness (i.e. competence and self-efficacy).

Q1. What do students report as to their own self-efficacy and positioning skills after using a virtual radiography simulation program?

Q2. What are students’ perceptions of their own self-efficacy and positioning skills after using the virtual radiography simulation program?

Research question 1 (RQ1) investigates students self-reported scores through a Likert scale survey instrument based on Shanahan (2016b). RQ1 is the quantitative phase of this mixed-methods study. Research question 2 (RQ2) seeks to explore students perceptions through interviews to explain the results of the quantitative data. RQ2 is the qualitative part of this mixed-methods study.

The participants in the study were 1st year radiography students at a 4 year higher institution in the intermountain West. These students have been accepted into the university’s RS Program and start the program each Fall semester. The students have no prior radiography experience, so all their learning comes during the RS program from didactic classes, laboratory sessions, and clinical time working with patients in hospitals or clinics. Results of the data collection were expected to be favorable self-reported self-efficacy and positioning scores after using the virtual simulation. Information gathered in the interviews helped explore in detail the most favorable and unfavorable self-reported survey scores.

Significance of the Study

The research questions were designed to investigate students' perceptions of their own self-efficacy and clinical skills (i.e. clinical preparedness) after using a virtual radiography simulation. This research is significant because all radiography education programs contend with the issue of preparing students for the clinical setting (Issenberg & Scalese, 2008; O'Connor et al., 2021; Yates, 2006). While no simulation or education can fully replace actual experience, students benefit from practice in a safe and risk free environment before performing exams on real patients. Many studies evaluating the use of virtual simulation have been performed in various medical education disciplines; however, little empirical research has been performed in the field of RS education.

Rationale for Methodology

The research questions, through multiple phases of analysis, sought to ascertain how students' self-efficacy and clinical skills were affected after using a virtual positioning simulation software program. This design followed an ESR mixed methods research (MMR) model (Creswell & Plano-Clark, 2018). The ESR occurs in two distinct yet interactive phases. The first phase starts with the collection and analysis of quantitative data. The second phase is the collection and analysis of qualitative data in order to help expand or explain the quantitative data of the first phase. The qualitative phase is designed as a result of the quantitative data (Creswell & Plano-Clark, 2018). This means the research methods and questions in the second phase are not established at the beginning of the research project. Instead they are developed after an analysis of the first phase data.

Using qualitative interviews to explain quantitative data provides a stronger support for conclusions drawn from the collected data than either method used individually. The rationale for mixing both types of data is that neither quantitative nor qualitative methods are sufficient by themselves to capture the trends and details of situations, such as the complex issue of radiography students' preparedness to enter the clinical setting. When used in combination, quantitative and qualitative methods complement each other and provide a more complete view of the research problem (Greene, Caracelli, and Graham, 1989; Johnson and Turner, 2003; Tashakkori and Teddlie, 1998).

Chapter Summary

Since X-rays were discovered in 1895, medical imaging has been an integral part of health care. RS has developed into its own medical field and profession. Though originally X-ray technicians were taught on the job and through the apprenticeship model, training eventually developed into a formal educational process. Today education in RS occurs in the formal learning environments of higher education as well as the informal learning environment of the clinical setting. When students and technologists are properly educated, the principles of radiographic exposure, positioning, radiation safety, quality patient care, and medical ethics can be appropriately applied and increase patient outcomes and safety.

RS students must complete a series of competence exams as part of their clinical education. They must meet ARRT criteria for these exams under the supervision of a registered radiologic technologist. Students must be prepared in the didactic and laboratory setting before they are ready to perform radiographic exams on real patients. Simulation is the most common practice for preparing RS students to enter the clinical setting. Virtual simulation is a new educational tool which has the potential to help supplement deficiencies in traditional simulation such as demands for time, space, and equipment. Few studies have researched the effectiveness of implementing virtual simulation into an existing RS positioning curriculum.

The purpose of this study was to investigate students' perceptions of their own self-efficacy and clinical skills (i.e. clinical preparedness) after using a virtual radiography simulation. Students who enter the clinical setting unprepared can produce sub-quality radiographic images, expose patients to unnecessarily high amounts of radiation, and decrease patient care. RS programs must establish a way to evaluate students' competence as part of preparing students to enter a clinical setting. A review of the current literature has shown how other allied health professions have used virtual simulation as an effective educational tool to prepare students to perform real life patient care skills; however, there is a lack this research directly relating to RS education. The conclusions drawn from this research can help provide educators a base of information on how students perceive their own clinical readiness after using a virtual simulation program and can guide further research studies of virtual simulation in health care education.

CHAPTER TWO: LITERATURE REVIEW

Radiographic science (RS) education, like all healthcare education, is uniquely different from education in other professional fields. While education for other professional fields (e.g. engineering, history, English, education, biology, etc.) focus solely on didactic or schoolwork learning, healthcare education is dually split between didactic and clinical education (Densen, 2011; Scheckel, 2009). Students are not only expected to acquire the technical, cognitive learning required, but they must also master the psychomotor skills necessary to apply didactic knowledge to patients in a clinical setting.

Historically, for adult learners, pedagogical techniques (i.e. teacher-directed methods) are often preferred by those who have progressed the furthest in formal education, as is the case with students in higher education (Cross, 1982). This is not surprising as the majority of organized education is based on pedagogical principles, and those with more education have more experience with and feel comfortable in well-structured classes and lectures (Hulse, 1992).

In contrast, modern learning theories for adult learners include self-pacing and the ability for repetition, real-time and learner-controlled feedback, and on-demand accessibility to education at the convenience of the learner (Cook et al., 2012; Decker, Sportsman, Puetz, & Billings, 2008; Kong et al., 2015; Olxaewski & Wolbrink, 2017). Traditional pedagogical techniques are not suited for modern adult learners in RS education. Students are required to learn radiological and medical theory and technical information before being able to apply that knowledge to a clinical setting. Educators must find ways to adapt modern learning theories for adult learners to successfully educate the next generation of healthcare professionals. Simulation, both real-life and virtual simulation, has been found to be the most common educational tool used to train and prepare modern students in healthcare (Motola et al., 2013; Shanahan, 2016a).

Real-life simulation, a common practice in radiographic education, is the use of high-fidelity mannequins, disarticulated phantoms, and real life people for the practice of radiographic positioning (Ahlqvist et al., 2013; Berry et al., 2007; Cook et al., 2012; Gordon et al., 2004; Kasprzak, 2016; Kong et al., 2015; Wright et al., 2006). Virtual simulation, technology-enhanced simulation performed through the medium of a computer software program, offers the added benefits of self-paced learning, repetition, constant access, and instant feedback (Issenberg & Scalese, 2008; Kasprzak, 2016; Shanahan, 2016a). This form of pedagogy is especially attractive to adult learners because they prefer interactive, hands-on learning with immediate feedback (Decker et al., 2008). More recent research is turning from traditional pedagogical models by identifying the uniqueness of educating adults, stating "Adults bring a plethora of knowledge and experience that can enhance their learning, as long as there is interactive, engaging, and collaborative instruction" (Whitney, 2014, p. 460).

Recently, the use of simulation has increased across the healthcare education continuum in such areas as patient safety, acquiring and honing clinical skills in a controlled environment, and promotion of individual and group learning (Monachino & Tuttle, 2015; Motola et al., 2013). In RS education, chief among these simulation trends is to improve psychomotor performance when preparing students to learn and practice in a clinical setting. The purpose of this chapter is to discuss the theoretical foundations for adult learning, the current use of simulation in RS education, characteristics to consider when implementing a simulation program.

Background

Clinical Requirements of Radiographic Science Programs

Students in RS education programs throughout the United States are required to learn and demonstrate the proper patient positions and radiation exposure factors for 37 mandatory exams and 34 elective exams in a clinical setting. Each exam is comprised of 2-6 images in differing patient positions, depending on the anatomy being imaged. Upon the successful completion of these exams, also known as "competencies", and the scholastic (didactic) components required by accredited RS programs, students are eligible to take a national registry exam given by the American Registry of Radiologic Technologists (ARRT). Successful completion of the ARRT exam allows students to become registered and certified radiologic technologists. This process of education and certification is similar to other medical professions such as doctors and nurses.

In RS education programs, program faculty teach students the technical and theoretical information necessary to perform all radiographic exams in classroom courses on campus. Clinical instructors (CIs) oversee, supervise, and evaluate students' competence as they perform these exams on patients in a clinical setting. The students start by learning the entry-level and most commonly performed exams, such as chest or hand exams. By the end of the educational program students must demonstrate competence in performing all required radiographic examinations in a safe and proficient manner. When students start the RS program, they have no previous experience with patient care and are often hesitant or unsure about positioning the patient and using the equipment to perform an X-ray examination. In medical imaging, when students are hesitant or lack knowledge and skills they are prone to produce images with decreased quality or expose patients to unnecessarily high amounts of radiation (Ortiz, 2015). Comfort, familiarity, and skills are acquired with time and practice, but these are experiences new RS students do not have.

To prepare students for the clinical setting, RS program faculty and CIs must find ways to develop student clinical competence. Competence is both a measurement of and indicator for student clinical preparedness; however, competence is not easily quantifiable (Williams & Berry, 1999), is ill-defined and subject to interpretation (Clarke & Holmes, 2007), and is vague (Castillo, Caruana, & Wainwright, 2011). The instructions given by the ARRT to educational radiography programs for determining student clinical competence is generalized and minimalistic:

> *Demonstration of clinical competence requires that the program director or the program director's designee has observed the candidate performing the procedure independently, consistently, and effectively during the course of the candidate's formal educational program. (ARRT, 2016)*

Competencies are performed on real patients in the clinical setting under the supervision of designated representatives of the program director (e.g. CIs). CIs use the following criteria identified by the ARRT (2016) to evaluate clinical competence: patient identity verification; examination order verification; patient assessment; room preparation; patient management; equipment operation; technique selection; patient positioning; radiation safety; imaging processing; and image evaluation. Many of the preceding criteria are subjective to the evaluator and determining competence can vary greatly among different CIs.

The goal of radiography education programs is to prepare students to be clinically competent in the classroom and laboratory setting before demonstrating that competence on real patients in the clinical setting. Currently there is a paucity of literature available on preparing students to enter the clinical setting as it directly relates to RS. Though little information was found, literature reviews conducted by other researchers about the preparedness of RS students to enter the clinical setting found common pedagogical themes including active learning, motivation, case-based studies, reflection, situations which require critical-thinking skills, objective structured clinical examination, and engagement activities (Holmström & Ahonen, 2016; Marshall & Harris, 2000; Sedden & Clark, 2016). However, the most common theme among the articles reviewed was the use of simulation. These articles touted the benefits of simulation for RS students but cited little empirical evidence of their implementation. The research mainly pointed to the use of simulation in other allied health professions and advocated the implementation of such techniques in RS education. Research suggests RS students benefit from the opportunity to practice radiographic examinations in a simulated environment prior to demonstrating that competence on real patients in the clinical setting (Holmström & Ahonen, 2016; Marshall & Harris, 2000; Sedden & Clark, 2016; Shanahan, 2016a).

Theoretical Foundations in Radiographic Science Education

Adult Learners

There are numerous educational learning and teaching theories which are particularly suited to medical education. Traditionally, as is expected in most areas of higher education, they primarily center on adult education theories. For adult learners, pedagogical techniques (i.e. teacher-directed methods) are often preferred by those who have progressed the furthest in formal education, as is the case with students in higher education (Cross, 1982). This is not surprising as the majority of organized education is based on pedagogical principles, and those with more education have more experience with and feel comfortable in well-structured classes and lectures (Hulse, 1991). Pedagogical techniques are also more suited for technical material and foundational or introductory information (Feuer & Geber, 1988). Such is the case with formal RS education. Students are required to learn radiological and medical theory and technical information before being able to apply that knowledge to a clinical setting.

Modern learning theories for adult learners include self-pacing and the ability for repetition, real-time and learner-controlled feedback, and on-demand accessibility to education at the convenience of the learner (Cook et al., 2012; Decker et al., 2008; Kong et al., 2015; Olxaewski & Wolbrink, 2017). Real-life simulation, a common practice in radiographic education, is the use of high-fidelity mannequins, disarticulated phantoms, and real life people for the practice of radiographic positioning (Ahlqvist et al., 2013; Berry et al., 2007; Cook et al., 2012; Gordon et al., 2004; Kasprzak, 2016; Kong et al., 2015; Wright et al., 2006). This form of pedagogy is especially attractive to adult learners because they prefer interactive, hands-on learning with immediate feedback (Decker et al., 2008). More recent research is turning from traditional pedagogical models by identifying the uniqueness of educating adults, stating "Adults bring a plethora of knowledge and experience that can enhance their learning, as long as there is interactive, engaging, and collaborative instruction" (Whitney, 2014, p. 460). Described in this paper are common teaching and learning theories used in RS education along with practical application of those theories.

Constructivism

Constructivism is built on the idea that "knowledge resides in the learner and that learning is a social activity enhanced by reflection, metacognition and inquiry" (Dangel, Guyton, & McIntyre, 2004, p. 237). Epistemology for constructivism is based in the concept that the teacher and the learner are linked, constructing knowledge together (Guba & Lincoln, 1994). Instructional principles tied to constructivism require students to (a) solve realistic and complex problems; (b) collaborate with others to solve those problems; (c) use multiple perspectives to examine the problems; (d) take ownership of the learning process instead of being passive recipients; and (e) become aware of their own role in the knowledge construction process (Driscoll, 2000; Reiser, 2001b). Learners actively create, interpret, and reorganize knowledge based on information gathered from their environment (Legg, Adelman, & Levitt, 2009). This means constructivism places emphasis on building knowledge when interacting with the environment to promote deep and lasting learning (Guba & Lincoln, 1994; Hoadley, 2004; Kolodner, 2004). Knowledge is then constructed when students reconcile formal instruction experiences with their existing knowledge, the cultural and social context in which ideas occur, and the environment created by the teacher. As students interact with the environment they create knowledge based on their interactions; this new knowledge is built on previously constructed knowledge. Students are involved in the learning process by means of understanding and reflecting on their environment. They learn through creating meaning based on real-life experiences, a key tenet of constructivism (Boger-Mehall, 1996; Reiser, 2001b).

In recent years constructivism has been applied through an emphasis on authentic learning (Reiser, 2001b). Authentic learning "is the idea that students should utilize their prior knowledge to engage with 'real' problems, tasks and challenges" (Splitter, 2009, p. 138). In RS education, as with all health care education, all learning relates to authentic tasks. Authentic tasks include acquiring a diagnostic image, reducing patient exposure to radiation, caring for a patient, basic nursing duties, and similar activities. The entire RS education curriculum is designed to support the transfer of knowledge to help the student become proficient in the clinical setting and develop as a professional in the field of radiology (Culp, 2015). As students use the knowledge they construct in the didactic and laboratory setting they are required to use this previously learned knowledge and apply it to new situations. New situations include recently learned radiographic positioning, patient type, and exam situation.

Culp (2015) demonstrated a particularly unique example of applying constructivist authentic learning to a cultural learning experience. RS students in the United States often have a lack of knowledge about other cultures and the role of radiologic technologists on an international scale. In this study, four RS students participated in global health observership experiences, traveling to two different countries to observe the practice of RS in those countries. The experience allowed the students to "construct an understanding of another culture through an authentic immersion" (Culp, 2015, p. 27). Through analysis of self-reporting by the students, self-motivated scholarship, and maintenance of relationships with international colleagues, the researcher concluded the experience had a positive impact on students and that the "travel changed their outlook on life and patient care for the better" (Culp, 2015, p. 27). This unique example demonstrates how constructivism and authentic learning is applied to RS education.

Cognitive Flexibility Theory

One particular theory based in constructivism that applies to RS education states cognitive flexibility creates meaning based on real life experiences. This is known as the Cognitive Flexibility Theory (CFT). CFT focuses on the nature of learning in complex and ill-structured domains, such as history, law, medicine, and teacher education (Boger-Mehall, 1996). Cognitive flexibility is the ability to restructure one's knowledge in response to changing situational demands. This happens as both the way knowledge is represented and the processes that operate on those mental representations (Spiro & Jehng, 1990). According to the CFT, the way in which learners are taught is a major influence on the type of cognitive structure they create. The way they store and structure knowledge they acquire determines how flexible they will be when the time comes to use that knowledge (Boger-Mehall, 1996). Concerned with transfer of knowledge and skills beyond initial learning, CFT emphasizes the presentation of information from many different perspectives and diverse examples.

Cognitive flexibility is achieved by manipulating the way knowledge is represented and the process that operates those mental representations. The CFT designates way three main ways in which this happens:

- Reflecting the knowledge complexly (matching the complexity of the situation) to learners providing opportunities to establish the interconnections of the concepts and principles. The instruction should avoid presenting the problems as simple, linear sequences of decision-making process.

- Providing content through multiple different ways. This can be done by giving students access to the content at different times, in different contexts, for different purposes, and from different perspectives.
- Supporting context-dependent knowledge: Knowledge cannot be oversimplified. The oversimplification isolates the knowledge from its context of use, segments the knowledge into discrete components, and represents the interrelationship of those components in a single unifying dimension. It is essential to provide contextual variability for different multiple knowledge representations and multiple interconnectedness of knowledge components (Spiro, Feltovich, Jacobson, & Coulson, 1991).

As was noted, the CFT is well suited to complex or ill-structured learning environments, such as medical instruction. For example, students could be taught by providing them with scenarios that require them to research information and ask questions. As they are busy constructing the solution, the scenario could be presented by the teacher in several ways, such as specific cases, multimedia presentations, jigsaw activities, and interactive games. Group discussion and brainstorming can integrate prior knowledge and new ideas. More information provided by the teacher could help link conditions and circumstances of this scenario to those which students have experienced previously. This causes students to use critical thinking skills to apply knowledge and skills from one area of knowledge to another.

Case Based Learning

Case-based learning (CLB) facilitates valuable learning by helping students interpret, reflect on, and apply experiences of their own or others. As the name implies, CBL is centered around cases. The use of CBL aids was born out of work in computer science on case-based reasoning and work in education on constructive approaches to learning (Kolodner, 2004; Reiser, 2001a). CBL is also a prevalent model in medical education. Medical education programs typically employ CBL techniques based on "two fundamental principles: basic sciences are learned in the process of analyzing typical cases, and learning is motivated by student curiosity" (Donner & Bickley, 1993, p. 294).

CBL is a specific paradigm based in the broader genre of problem-based learning (Williams, 2005). Problem based learning centers on the learner and empowers them to learn through activities such as conducting research, integrating theory and practice, and applying knowledge and skills to develop a viable solution to a problem (Savery, 2006). CBL makes three types of suggestions with respect to educational practice (Kolodner, Dorn, Thomas, & Guzdial, 2012; Savery, 2006). Educators should engineering the sequence in the learning environment. Learning from experience takes time and repetition. The sequence of activities needs constructed in a way that gives students frequent access to cases in their memory and gives application to different scenarios based on that knowledge. Educators should support student reflection. CBL depends on learner reflection so they recall knowledge and effectively use it later. The instructors task is to help students have a desire to interpret their experiences and provide prompts for more productive reflection. And educators should use case libraries as a student self-resource. Collections of cases and experience act as an external memory for the learner.

Having students write personal experiences as cases not only helps the student reflect and apply knowledge, but adds to the general case repository for future use.

Case based reasoning (CBR) is a model of cognition that integrates reasoning, learning, and memory. Reasoners seek to navigate the world by successful completion of goals. Experiences had by the reasoner, some good and some bad, help them to learn about its environment and the ways they can use the environment to achieve goals. The reasoner stores the experiences gained by creating a personal knowledge that can later be retrieved and used in a different situation (Savery, 2006). Reasoners engage in noticing differences and similarities between situations and can draw conclusions about the situation based on these differences/similarities compared to previously stored experiences. Essential to their learning are two key principles: failure, and the interpretation of experiences.

The implications of CBR match those made by constructivist approaches to learning and education. A particular approach to constructivism, constructionism, suggests experiences involving the active construction of an idea or knowledge are particularly good for promoting such knowledge development (Kolodner et al., 2012; Papert, 1991). CBR suggests five facilitators for learning effectively from hand-on, creative experiences (Kolodner et al., 2012; Williams, 2005):

1. having the kinds of experiences that afford learning what needs to be learned;
2. interpreting those experiences so as to recognize what can be learned from them (drawing connections between their parts so as to transform them into useful cases and extracting lessons that might be applied elsewhere);

3. anticipating their usefulness so as to be able to develop indexes for these cases that will allow their applicability to be recognized in the future;
4. experiencing failure, especially failure of one's expectations, explaining those failures, and trying again (iteration); and
5. learning to use cases effectively to reason

Experiences should afford concrete, authentic, and timely feedback so learners can have time to process the experience and draw personal conclusions. Based on the cognitive model, CBR should provide an environment safe for failure and for carrying out constructs, not just thinking about ideas, and push learners to both predict and explain outcomes. Educators should then help students try out ideas in a variety of situations and applications multiple times and then reflect on and assess experiences to acquire knowledge and the ability to apply it to different situations (Donner & Bickley, 1993; Kolodner et al., 2012). Experimentation and reflection encourage learners to reuse their own experiences in a controlled environment and draw on outside experiences to apply knowledge to situations with which they are not familiar.

CBR can have a variety of applications in medical education, particularly RS. Radiographers are involved in “cases” with each patient they image. Each patient is unique and possess distinctive challenges. Preparing students with mock patient scenarios using CBL can prepare students for those unique, real life challenges. “By providing experience with a variety of concrete cases, the case method expands and sharpens students’ understanding of the profession” (Dowd & Wilson, 1995, p. 171). The skills and adaptations used in training situations translate to real situations in the clinical setting (Terashita, Tamura, Kisa, Kawabata, & Ogasawara, 2016; Wilbanks, 2009). Examples of cases used in RS education include plain radiography positioning techniques, human diversity, radiographic anatomy, ethics and law, radiographic exposure, critical thinking skills, (Dowd & Wilson, 1995; Kowalczyk & Leggett, 2005; Terashita et al., 2016; Wilbanks, 2009).

Social Learning

Social learning theory (SLT) is an educational theory that defines learning as a function of both the environment and mental processes. Therefore it is a combination of behaviorism and cognitive learning theories (Ormrod, 1990; Rosenthal & Zimmerman, 1978). In particular, attention is given to the impact of social variables, such as the behavior of models, on human cognitive processes (Rosenthal & Zimmerman, 1978). Social learning has four key elements:

1. people can learn by observing the behavior and consequences of others;
2. learning and performance are not the same thing and cannot be performed at the same time;
3. reinforcement is a part of the learning process;
4. and cognitive process play a role in learning (Ormrod, 1990).

SLT emphasizes a "reciprocal relationship between the process of cognition and the information derived from the environment" (Rosenthal & Zimmerman, 1978, p. 27), while learning science theorists postulate a linear flow of information (Hoadley, 2004; Rosenthal & Zimmerman, 1978).

RS programs incorporate the principle of SLT. Students can be directed to develop both practical and communication skills by learning through observation of working technologists (Upadhyay & Williamson, 2010). During the RS program, students incrementally increase in their skills and what is expected of them. They learn the norms and social cues of how to operate in a clinical setting, along with departmental policies and standard operating procedures by mentorship of professional staff in a clinical setting. The qualities and traits are then rewarded when followed or punished when not fitting the standard. These characteristics help define the community of RS and help differentiate it from other communities and fields (Hoadley, 2004). The broad theory of "social learning" encompasses multiple educational theories including collaborative learning and self-efficacy.

Collaborative learning.

Collaborative learning (CL) is based on the idea that learning is a social process which takes place through social interactions. Social interactions, or conversations, occur through group discussions, cooperative problem solving, and performing tasks or creating products in pairs or small groups so individual members must work together to accomplish a common goal (Johnson, Johnson, & Smith, 2013; Kowalczyk & Copley, 2013; Yates, 2006). Students become responsible for their own learning, leaving the educator to facilitate the learning process instead of serving as the primary focus of learning (Johnson et al., 2013; Kowalczyk & Copley, 2013; Maihoff, 1994). Also, CL promotes higher individual knowledge and proficiency than does competitive or individualistic learning (Johnson et al., 2013). Educators use CL to leverage the talents and knowledge of individuals to help the group learn.

CL strategies may be useful in allied health professions such as RS. In a study by Akroyd and Wold (1996), a survey was given to a large sample of radiology administrators. The administrators rated the importance of various workplace skills and the ability of graduate radiologic technologists' ability to perform those skills. Most prominent among the results were appropriate interpersonal skills, effective communication, creative problem solving, and creative thinking. These important characteristics have been identified as benefits of CL (Yates, 2006).

Many CL strategies are used in RS education. One example is practical laboratory sessions. Laboratory exercises break students into small groups which are then given a series of tasks to complete an experiment. The students work together to complete the tasks and then collaborate on how to answer a set of given questions based on the data they collected through the experiments. The instructor then helps facilitate a review of the experiment and the findings through a guided discussion. Another example is student research. Students are assigned to groups and given the task to research a topic of radiographic exposure which they will then present as a scientific poster. Students must take the knowledge and information they collectively possess and apply a scientific research method to investigate a principle of radiographic exposure. The group presents the research in the form of a poster and gives a presentation to the rest of the class. Based on the feedback of the class and the instructor, the research team makes corrections and edits to prepare for presenting the poster to the public in a research forum. The most common form of collaboration in RS education comes from giving student pairs the opportunity to perform radiographic exams on patients in a clinical setting. After receiving the required didactic knowledge and laboratory practice, students are assigned to work as pairs to complete radiographic exams on real patients. The students have to work together to perform proper positioning, image acquisition, and image evaluation. They must ensure the exam has the diagnostic information necessary for the radiologist to read the images and identify a correct diagnosis. This process applies all the benefits of CL to a real life, patient care setting.

Self-efficacy.

Another concept grounded in social learning theory is self-efficacy. According to social learning theory, secondary drives (i.e. those motivating factors other than basic primary drives such as hunger and thirst) develop as behaviors and are reinforced or rewarded (Kitching, Cassidy, Eachus, & Hogg, 2011). Each individual has a self-system which enables them to exercise a measure of control over their own feelings, thoughts, motivations, and actions. This "can-do" realization give the individual a sense of mastery over their environment (Bandura, 1997). "Self-efficacy refers to beliefs in one's capability to organize and execute the course of action required to produce given attainments" (Bandura, 1997, p. 3). Self-efficacy is how a person perceives their own ability to accomplish a goal, relating only to a particular subject or activity. This differs from self-esteem, which is confidence in one's own worth or abilities (Bandura, 1997; Kitching et al., 2011). Higher levels of self-efficacy tend to be tied to higher performance (Bandura, 1997; Kitching et al., 2011). The process of establishing self-efficacy can be seen as a positive or negative feedback mechanism. If someone believes they can perform the behavior necessary to complete a task, they will strive to do so longer and are more likely to be successful because of their perseverance.

There is a paucity of self-efficacy literature available in the field of radiographic science education. Researchers have touted the merits of studying self-efficacy in relation to radiological patient safety (Watson & Odle, 2013), as a theoretical framework for image quality scale creation (Mraity, England, & Hogg, 2014), and in medical education

(Artino, 2012), but none provide any empirical data to support their claims. A few researchers have performed empirical studies of radiological self-efficacy related to interprofessional collaboration (Nørgaard et al., 2013), racial identity (Herrmann & Martin, 2017), clinical leadership (Booth, Henwood, & Miller, 2017), instructors perspectives of online teaching (Cherry & Flora, 2017; Kowalczyk, 2014), and how students receive CI feedback in the clinical setting (Nolan & Loubier, 2018), but almost no empirical research has investigated radiographic student self-efficacy in relation to clinical preparedness. In addition, most of the aforementioned studies are specifically related radiographic science clinicians and educators, not to radiographic science students.

As noted, self-efficacy is domain specific, meaning one's perception of his or her own ability to accomplish a goal or task is dependent on the specific goal or task. "In social cognitive theory, an efficacious personality disposition is a dynamic, multifaceted belief system that operates selectively across different activity domains and under different situational demands, rather than being a decontextualized conglomerate" (Bandura, 1997, p. 42). Because one's perceived efficacy is not a contextless global disposition, self-efficacy should be measured in terms of a particular domain, task, or goal (Bandura, 1997). A high sense of self-efficacy in one activity is not necessarily associated with high self-efficacy in another realm (Bandura, 1997; DiClemente, 1986; Hofstetter, Sallis, & Hovell, 1990). Therefore, instruments and measures of self-efficacy must be tailored to specific domains and activities.

Since self-efficacy is context specific, the use of a "general" self-efficacy scale or instrument is of little relevance when attempting to measure a specific set of perceived abilities or behaviors (Kitching et al., 2011). Because using non-relevant self-efficacy scales is ineffective and no relevant scales existed, Kitching et al. (2011) developed a self-efficacy scale for radiographic science students. The instrument was compiled from seminal student nursing self-efficacy studies (Lim, Downie, & Nathan, 2004; McConville & Lane, 2006; Shellman, 2007) and adapted to radiographic science students. The instrument was validated with in a pilot study and was shown to have a high degree of internal reliability (Cronbach alpha 0.92), making this instrument the first of its kind to analyze radiographic science student self-efficacy. However, the scale developed by Kitching et al. is a general instrument of radiographic science student self-perception and not specifically geared toward any educational pedagogy. No known self-efficacy instrument exists for radiographic science students in relation to virtual simulation or clinical preparedness.

<u>Distributed Practice</u>

The principle of repeating a learning experience or scenario over a period of time is called distributed practice (aka the spacing effect). Distributed practice is the "technique of distributing study or learning efforts over multiple short sessions, with each session focused on the subject matter to be learned" (Kapp, 2012, p. 65). Repeated learning or experience over time helps learned activities to transition from short-term to long-term memory. This long-term learning helps learners retain access to memorized information over long periods of time (Kapp, 2012; Tshibwabaw et al., 2017). Distributed practice can help learners "retain access to memorized information over long periods of time because the spacing prompts deeper processing of the learned material" (Kapp, 2012, p. 65). Another, albeit counterintuitive, explanation is that allowing time for forgetting during the interval between successive learning experiences promotes learning; the less accessible an item is in memory because of forgetting, the more memory of that item is strengthened when it is successfully retrieved (Slone & Sandhofer, 2017). Therefore, learning through distributed practice is a function of repetition and cognitive effort.

Studies indicate that distributed practice can speed learning and increase knowledge retention more so than massed practice (i.e. cramming) in medical education (Hulse, 1992; Nkenke et al., 2012; Robertson, Paige, & Bok, 2012). In repeatedly experiencing an educational scenario, learners can improve on past performance, sometimes seen in the form of additional score, a higher academic grade, or increased patient experience. Each iteration of a scenario leads to increased learning, but the effects are only seen after a period of time and not immediately. Educational experiences in medical education should be designed to be repeatable while still being engaging to keep learners involved when using the principle of distributed practice. Students engaged in repeated learning scenarios gain confidence through successful application of previously learned knowledge, reinforcing the transition of knowledge from short-term to long-term memory.

When confidence is gained and difficulty increases, the learner is drawn to reattempt the same or similar situations, analogous to the way healthcare workers apply the same principles and techniques to multiple, varying situations. In RS education, distributed practice is a common method to teach students about medical imaging. Instruction is given over the broad topic of RS, but in each class students are taught separate yet overlapping topics by various instructors through differing methods. The information is distributed and spaced over the duration of the educational program. Over the 2 year period of the program, students incrementally increase in their skills, and consequently what is expected of them. Distributed practice is especially useful for medical educational programs, such as RS, which require students to retain information gathered for over two years or more before taking a national certification exam. When simulation is incorporated in RS education, it allows students to practice and re-practice psychomotor skills and positioning techniques. Students use knowledge and experience gain in previous simulation sessions and apply it to new situations. Virtual simulation give the added benefits of practice and learning in a safe environment without the need of physical space or time dedicated in a laboratory or clinical setting. The learning theory of students building new knowledge on preexisting knowledge, known as constructivism, has previously been discussed.

Theoretical Framework

Activity Theory

Understanding how students interact with virtual simulation is essential to determining if and how learning has occurred. One useful framework for examining the implementation of virtual simulation in healthcare education is Activity Theory (AT). Though Vygotsky (1981) originally developed the foundation of what would come to be known as AT, the modern AT model of learning mediated by tools was cultivated and expounded by Engeström (2001). Nardi (1996) claims that “Activity theory is a powerful and clarifying descriptive tool rather than a strongly predictive theory” (p. 7); therefore, AT can be a useful tool in analyzing student interactions with an educational tool. AT disputed the contemporary stimulus-response model of the time, and promoted the idea that human activity is purposeful and used tools to carry out a set of actions (Hasan & Kazlauskas, 2014). Therefore, analysis of the activity requires further investigation of its parts: subject, tool, and object (see Figure 1). This is commonly known as the first generation of AT (Engeström, 2001).

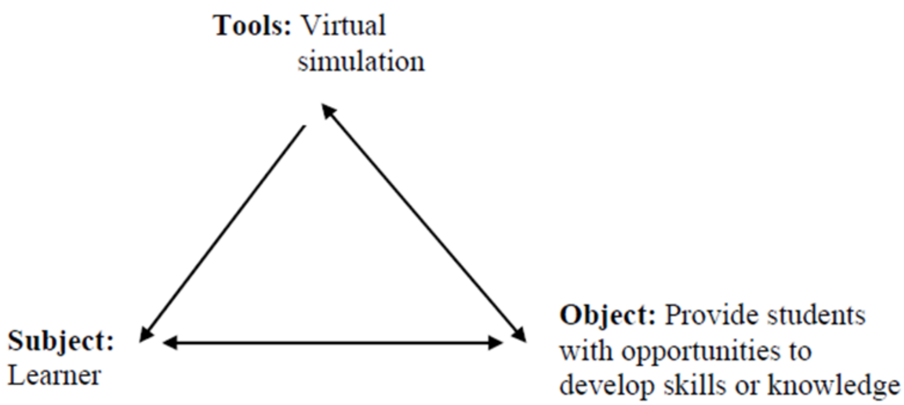

Figure 1. 1st Generation Activity Theory

In 1st generation AT, the *subject* is defined as the person or group engaged in an activity, i.e. the learner (Nardi, 1996). The learner engages in the activity purposefully using tools to reach a predetermined goal (Vygotsky, 1981; Wilson, 2006). *Tools* are used by the learner to support the learning process (Shanahan, 2016b). Tools can be outward or external tools (i.e. a computer, software program, or simulation equipment) or can be inward or internal tools (i.e. learning schema, strategies, or instructions) (Cole & Engeström, 1993; Shanahan, 2016b). Tools develop the relationship between the subject and the object (Issroff & Scanlon, 2002). The *object* is the final part of the triad and refers to the goal of the learning activity (Kaptelinin & Nardi, 2006). In healthcare education, the goal may be to provide students with opportunities to learn didactic knowledge and improve clinical skills.

While the subject – tool - object model is referred to as first generation AT, which focused on the action of the individual, Engeström (2001) argued the actions of individuals cannot be understood without taking into account the activity of the whole system or the environment. Engeström expanded the original AT triad into a collective activity system model, generally regarded as second generation AT (Engeström, 2001). The AT original model is represented in the uppermost sub-triangle, with the added collective activity system in the lowermost portions of the larger triangle.

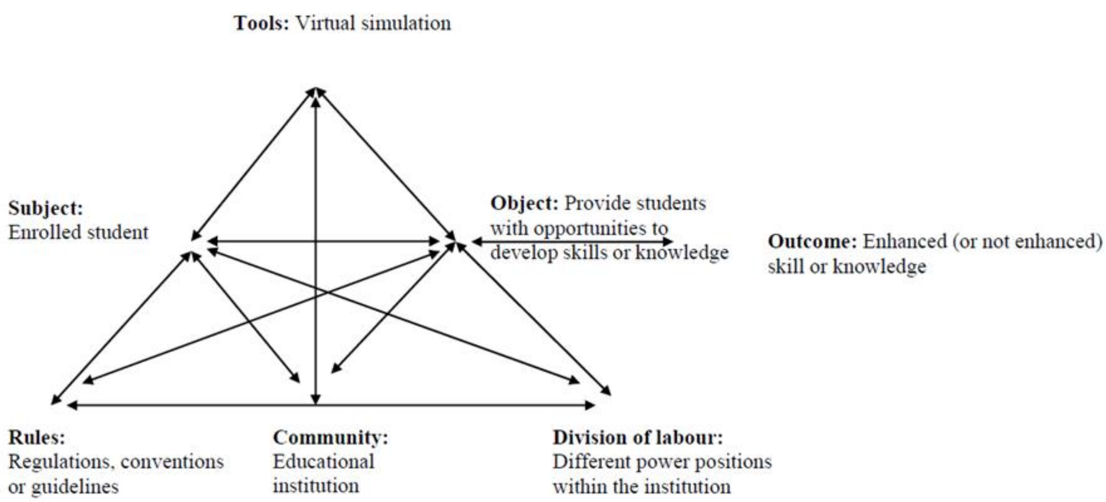

Figure 2. 2nd Generation Activity Theory

Second generation AT (see Figure 2) expands beyond the original triad and recognizes that subjects, objects, and tools of an activity operate within a larger system of community, rules, and divisions of labor (Engeström, 1987). *Community* refers to the larger social environment in which the activity takes place (Engeström, 1987; Wilson, 2006). Learning in an educational setting can involve both individual and shared knowledge construction. As an individual activity, the learner engages with the tool to construct meaningful knowledge (Grabowski, 2004). However, through collaboration with others in the learning environment, learners can engage in an exchange of opinions and ideas (Jonassen, Howland, Marra, & Crismond, 2008; Wenger, McDermott, & Snyder, 2002). Through this shared process, constructing knowledge expands beyond the learner and becomes an active process of developing shared meaning amongst learners (Jonassen et al., 2008).

The relationship between the subject and the community is mediated by rules (Issroff & Scanlon, 2002). *Rules* are abstract constructs which govern the activity, or a set of conditions that help to determine how and why the individuals may interact with the activity (Hashim & Jones, 2007; Kaptelinin & Nardi, 2006; Wilson, 2006). Rules act as a source of tension since they allow or constrain what is permitted within the system (Shanahan, 2016b). The establish boundaries or set the expectations of interaction between the subject and the tool. The relationship between the community and the object is mediated by the division of labor (Issroff & Scanlon, 2002). *Division of labor* is the explicit and implicit organization of a community and can be roles assigned (officially or unofficially) to each person participating in the activity system, as related to the transformation process of the object into the outcome (Issroff & Scanlon, 2002; Ndenge, 2017). In a traditional educational setting, division of labor can be split between teacher-led or student-led activities. However, with the development of self-regulated learning environments (e.g. asynchronous online learning, augmented and virtual reality, adaptive learning tools, etc.) the schema or pedagogy used to guide the learner can take on the role traditionally assigned to teachers (Russell, 2001). The division of labor can move in such a way that tools can take on role of instructor instead of solely being a used device.

AT provides a theoretical framework by which the effectiveness of implementing a tool, such as a simulation program, can be evaluated. The various components of AT interact in a system of combined constructs. By looking at the interactions between and among constructs, researchers can dissect how and in what ways a tool is being used and if the method of use is effective in achieving the desired outcome.

Review of Simulation Literature

Simulation (both live and virtual) has been identified as the most common method of helping students prepare to perform radiographic examinations on real patients in hospitals and clinics (Ahlqvist et al., 2013; Berry et al., 2007; Cook et al., 2012; Gordon et al., 2004; Kasprzak, 2016; Kong et al., 2015; Shanahan, 2016a; Wright et al., 2006). According to the Society for Simulation in Healthcare (n.d.), healthcare simulation “is a range of activities that share a broad, similar purpose – to improve the safety, effectiveness, and efficiency of healthcare services” (para. 1). This is often accomplished through various modalities within scenarios that seek to achieve a degree of realism to facilitate experiential learning (Cook et al., 2011; Issenberg, McGaghie, Petrusa, Gordon, & Scalese, 2005; McGaghie, Issenberg, Cohen, Barsuk, & Wayne, 2011). Real-life simulation in radiographic education is the use of high-fidelity mannequins, disarticulated phantoms, and real life people for the practice of radiographic positioning (Ahlqvist et al., 2013; Berry et al., 2007; Cook et al., 2012; Gordon et al., 2004; Kasprzak, 2016; Kong et al., 2015; Wright et al., 2006). This form of pedagogy is especially attractive to adult learners because they prefer interactive, hands-on learning with immediate feedback (Decker et al., 2008).

Simulations, aka real life simulated learning scenarios, seek to “imitate real patients, anatomic regions or clinical tasks, or to mirror the real-life situations in which medical services are rendered” (Issenberg & Scalese, 2008, p. 33). The safe and risk-free environment offered through simulation gives students the ability to practice health care skills without endangering patients (Berry et al., 2007; Cook et al., 2012; Gordon et al., 2004; Kasprzak, 2016; Kong et al., 2015). For students who are training in healthcare related fields, simulation is an alternative educational method for situations when training in real-life scenarios is time consuming, expensive, or hazardous to themselves or to patients (Ahlqvist, et al., 2013). Simulated learning scenarios also allow students to receive immediate and specific feedback about their performance from an evaluator (Cook et al., 2012; Kong et al., 2015; Wright et al., 2006). Multiple studies have shown medical simulation to be educationally affective (Ahlqvist et al., 2013; Gaba, 2004; Issenberg et al., 2005).

Virtual Simulation

While classroom and laboratory simulations have been a staple of medical education, recently there has been a migration of simulations into the virtual environment (Kasprzak, 2016). Virtual simulation generally falls under the broader category of serious games (i.e. games developed for a purpose other than entertainment) (Bauman & Ralston-Berg, 2015; Olxaewski & Wolbrink, 2017; Wang, DeMaria, Goldberg, & Katz, 2016). Virtual simulation is the use of technology-enhanced simulation for the same purpose as real-life simulation but performed through the medium of a computer software program (Issenberg & Scalese, 2008; Kasprzak, 2016; Shanahan, 2016a). Examples may include the user manipulating a 3rd person avatar to accomplish tasks or spatially move through a virtual setting, or a 1st person setting where the user interacts with the virtual environment as they would on their own (i.e. instead of using and manipulating an avatar). Virtual simulation may also include real life instruments and tools used in combination with a virtual environment (Tjiam et al., 2014). A study by Tjiam et al (2014) had the user look at a computer screen which portrayed a virtual surgery simulation while the user manipulated real life surgical tools. The virtual simulation then portrayed the movement of the real life tools in virtual space displayed on the monitor. The goal of virtual simulation is to imitate of a real-world process (Olxaewski & Wolbrink, 2017). This new form of simulation has been shown to increase student satisfaction and learning when compared to traditional teaching methods (Bauman & Ralston-Berg, 2015; Olxaewski & Wolbrink, 2017; Shanahan, 2016a).

The benefits of real life simulation are also found in virtual simulation with some additional advantages. Virtual simulations reduce the need for tangible products and physical space. Because of the virtual nature of the simulations, students can use the technology in any environment at any time. Virtual simulations can provide a scalable, convenient method for students to practice clinical skills in a safe environment while using interactivity and competition (Berry et al., 2007; Kasprzak, 2016; Olxaewski & Wolbrink, 2017). The gaming characteristics found in virtual simulation use motivational factors and cognitive scaffolding to promote learning and engagement (Bauman & Ralston-Berg, 2015; Olxaewski & Wolbrink, 2017). Learning theories for adult learners are applied through self-pacing and the ability for repetition, real-time and learner-controlled feedback, and on-demand accessibility to education at the convenience of the student (Cook et al., 2012; Decker et al., 2008; Kong et al., 2015; Olxaewski & Wolbrink, 2017).

Like real-world simulations, virtual simulations “allow students to develop their understanding and practise their skills, in a safe pre-clinical learning environment”

(Shanahan, 2016a, p. 218). Radiation therapy educational programs, which is similar but separate from RS, have found virtual simulation allowed student to practice technical skills which led to increased student confidence (Bridge, Appleyard, Ward, Phillips, & Beavis, 2007; Bridge et al., 2016; Green & Appleyard, 2011). Virtual simulation led to students being better prepared to perform in the clinical environment (Bridge et al., 2016). Students cited the safe learning environment of virtual simulation allowed them to develop their skills without endangering patients, provided the ability to make and learn from mistakes, and decreased time pressure that occurs in the clinical environment as factors which lead to their increased performance (Bridge et al., 2007; Bridge et al., 2016; Green & Appleyard, 2011; Shanahan, 2016a). Similar benefits of narrowing the gap between psychomotor skills acquisition and clinical practice were found when using virtual simulation in certain surgical education trails (Berry et al., 2007; Densen, 2011; Gordon et al., 2004; Tjiam et al., 2014).

Virtual simulation, a method used for training in multiple industries, is increasingly being incorporated in health care education (Ghanbarzadeh, Ghapanchi, Blumenstein, & Talaei-Khoei, 2014; Ma, Jain, & Anderson, 2014). This educational method has been used to assess and support interdisciplinary learning and communication skill development (Shanahan, 2016a; Lemheney et al., 2016). Virtual simulation holds promise for maximizing access and minimizing the cost of training simulation. Examples in health care include procedural simulation, objective structured clinical examinations, patient safety, patient education and engagement, teamwork, and replacing live patient encounters. The dynamic learning environment provided by virtual simulation is based in the theory of social participation: the concept of forming knowledge through interaction with other people (Berragan, 2011; Lemheney et al., 2016). However, until recently, most virtual simulations have been designed for specific health care professions rather than interprofessional health care teams (Shanahan, 2016a; Lemheney et al., 2016). Effective communication and interprofessional collaboration, generally considered as part of clinical competence, are essential to maintain high standards of health care.

Simulation can be used as a tool for assessing learning and skills rather than strictly for the teaching of skills. Assessing student learning and skills is an essential part of determining clinical readiness. A difficulty with real-life simulation is that the evaluator can be influenced by other factors outside of the simulation performance (i.e. personal relationships, individual preferences, sickness, mood, etc.) making their evaluation more subjective instead of strictly objective. However, unlike traditional simulation, assessments given through virtual simulations can offer an objective, standardized model for students to achieve metric benchmarks and immediate feedback without the bias of a human evaluator (Berry et al., 2007). Berry et al. (2007) found virtual simulations to be as effective as laboratory simulations in assessing technical skills in certain radiology procedures. Sabir, Aran, and Abujudeh (2014) agreed and additionally stated how simulations will be "more commonly used as an assessment tool as professional boards start to include simulation-based assessment in their certification and recertification procedures" (p. 513). However, these studies focus on the use of simulation as a method of assessment for doctors training to become radiologists (i.e. health care workers who specialize in the interpretation of radiographic images). On the other hand, radiographers, or radiologic technologists, are the medical professionals who perform medical imaging exams to acquire radiographic images. Currently the available literature about simulation's use in RS focuses on its educational effectiveness and impact on clinical performance; little to no research has been performed on how simulation can be used as an assessment tool in the field of radiologic science.

Though virtual simulation offers many benefits to medical education, there are disadvantages. The introduction of new simulation software can cause technical difficulties which may diminish learning opportunities (Burden et al., 2012; James, Maude, Sim, & McDonald, 2012; St. John-Matthews, Gibbs, & Messer, 2013). Also, some studies have shown the ease of use and competence of using computers is associated with gender and age differences. Both Huffman, Whetten, and Huffman (2013) and Teo, Fan, and Du (2015) explored the relationship between technology self-efficacy and gender roles among university students. They found males report higher levels of self-efficacy in their own computing skills and competence than females. Helsper and Eynon (2010) reported in a study of United Kingdom citizens that those born with access to computers and the internet (i.e. digital natives) have higher confidence in their computer abilities than those born before such technologies were available (i.e. digital immigrants); however, their findings did show digital immigrants can become as proficient with technology as digital natives through practice and acquiring skills. Based on these findings, student cohort differences as well as technological issues may impact the introduction of virtual simulation and its educational value. Despite the potential negative effects, virtual simulation can be used as a valuable educational tool when implemented properly (Shanahan, 2016a). Based on the clinical education and competence requirements set by the ARRT, the attributes of virtual simulation are uniquely suited to fit the needs of educating and training RS students.

Virtual Simulation in Radiographic Science

Simulation in radiology has been used for many years in the form of “hot seat” conferences, case studies, and online teaching modules; however, truly immersive virtual simulations are new to the field (Desser, 2007). Primarily, virtual simulation has been used in healthcare to improve technical skill development. A summary of simulation options and uses in medical imaging education is shown in Table 1. With virtual simulation, the risk-free environment of simulated scenarios is combined with the freedom and versatility of the virtual world (Berry et al., 2007; Chetlen et al., 2015; Cook et al., 2012; Gordon et al., 2004; Kasprzak, 2016; Kong et al., 2015; Shanahan, 2016a). Virtual simulation also provides a training scenario that is less awkward than students practicing on study participants or patients (Burden et al., 2012; Coline, Gihad, Philippe, & Yves, 2015; Desser, 2007; Lemheney et al., 2016; Shanahan, 2016a). For medical imaging specifically, there is an increasing trend to use virtual simulation for medical doctors’ training in radiology to increase interpretative skills. Other skills that can be acquired through virtual simulation include “management of contrast reactions, interpersonal and communication skills, professionalism, and team training” (Chetlen et al., 2015, p. 1253).

Table 1. Summary of Simulation Use in Medical Imaging Education

Simulator Options	**Procedural Skills Training**	**Non-Procedural Skills Training**
Types of Simulators • Part-task trainers ○ Head, neck, and torso mannequins ○ Practice ultrasound biopsy equipment • Simulated patients ○ CPR dummies ○ Full body, computerized mannequins • Immersive simulators ○ Computer programs ○ Virtual reality Simulator Fidelity • Low (least expensive an static) • Medium • High (most expensive and sophisticated	Radiography • Virtual patients for positioning and image analysis • Simulated radiation dosages Sonography • Practice mannequins • Simulations of uncomfortable/invasive exams • Part-task trainers Other Modalities • Radiation dose simulations in Nuclear Medicine • "Moving heart" thoracic studies in CT and MRI • Interpersonal skills	Image Interpretation • Virtual workstation • Simulated DICOM and PACS training • ACR virtual teaching files Professionalism and Communication • Virtual patients for communication practice • Simulated interprofessional exams • Simulated exams to increase confidence

Simulator Options

Types of Simulators

There are various types of simulators used to train radiology professionals. Part-task trainers range from rudimentary to high-tech and represent one body part or a limited portion of reality so those training can focus on one particular skill (Chetlen et al., 2015; Desser, 2007; Klein & Neal, 2016). For example, there are head, neck, and torso mannequins for teaching venipuncture and line placement, and ultrasound simulators to hone scanning abilities or practice needle guided biopsies. Simulated and standardized patients are also a common simulator in radiology and are generally mechanical, virtual, and computer-enhanced mannequins. Cardiopulmonary resuscitation (CPR) dummies such as Resusci Anne and SimMan are used to simulate real patients and can be given symptoms and reactions through a computer to enhance the situation for the trainees (Chetlen et al., 2015; Desser, 2007; Klein & Neal, 2016). Finally, there are also virtual reality and immersive simulators. These use computer displays to simulate the physical world and use auditory, visual, and tactile feedback to guide the user through the scenario (Chetlen et al., 2015; Desser, 2007). The VIST-Lab in Sweden is a fully immersive interventional lab to teach endovascular procedures (Chetlen et al., 2015).

Simulator Fidelity

Fidelity describes the "degree to which the simulation matches the actual experience, as well as the level to which the skills in the real task are captured in the simulated task" (Klein & Neal, 2016, p. 909). Simulators are ranked as low-, medium-, or high-fidelity and range from inexpensive and static to sophisticated, computerized, and expensive (Wagner, 2017). Fidelity is measured in terms of equipment, environmental, and psychological realism. Most radiology procedures can be completed using low- or medium-fidelity equipment, decreasing the necessary cost required (Klein & Neal, 2016). No matter the fidelity of the simulator, the possibilities within radiology are growing and range from procedural skills training in multiple modalities to interpersonal skills for radiologists and technologists.

Procedural Skills Training

Radiography

A simulator was introduced in 2006 that utilizes a high-resolution computed tomography (CT) data set of the head and spine to create a virtual patient for technologists to practice positioning for cervical spine radiographs. Students manipulate a virtual tube and X-ray beam using computer animation and the resultant X-ray image is produced using algorithms and no radiation (Wagner, 2017). This allows students to evaluate their positioning performance without offering any radiation risk to patients (Desser et al., 2006). Pediatric radiography is another opportunity for virtual simulation. Pediatric patients require a change in radiation and contrast dosage and provide unique positioning and technique challenges. Virtual simulation has been used to estimate radiation dosages, present positioning challenges, mimic contrast reactions, and display pathology and anomalies specific to pediatric patients (Gaca et al., 2007; Stein-Wexler et al., 2010).

Interventional Radiology

Interventional radiology procedures are a highly-utilized modality for virtual simulations. Ultrasound and CT guided percutaneous procedures, neuroradiology, vascular interventional procedures, and catheter-based interventions, as well as training for acute radiologic emergencies, have all been practiced using virtual simulation (Chetlen et al., 2015; Desser, 2007). Using virtual simulation for these procedures have been shown to reduce fluoroscopy time, radiation dose, needle redirects, and overall procedure time (Chetlen et al., 2015). The establishment of virtual simulation in interventional radiology also sparked the use of these devices for competing departments, such as vascular surgery and cardiologists. Simulators such as the Procedicus VIST simulator, Angio Mentor, Simsuite, and CathLabVR system have all been developed and are undergoing validation studies (Desser, 2007).

Sonography

In the realm of medical imaging, sonography (aka ultrasound) imaging is a field similar to, but separate from RS, and is one such specialty benefitting from the use of virtual simulation. UltraSim, a sonographic simulation system, "consists of a full-size mannequin with realistic body contours and a soft torso surface, an ultrasound probe, and an ultrasound scanner console and monitor" (Desser, 2007, p. 820). This simulator was used in a study of 8 first-year residents for abdomen and pelvis scanning, where the investigators determined the simulator improved the residents' scanning abilities and interpretation skills (Monsky et al., 2002). Gynecological imaging exams are uncomfortable for both the patient and the inexperienced examiner, which can lead to increased stress and decreased image quality (Burden et al., 2012; Coline et al., 2015). Virtual simulation allows for the training of sonographers without the pressures of a live patient setting and possible repeat interventions, "thus accelerating the learning curve in a nonclinical environment" (Coline et al., 2015, p. 1663). Also, phantoms can be used to simulate patients for transthoracic and transesophageal echocardiography including 3D tracking (Chetlen et al., 2015).

Other Modalities

Virtual simulation can also be used in modalities such as nuclear medicine, CT, and magnetic resonance imaging (MRI). In nuclear medicine, training can be performed on the use of radiopharmaceuticals, including proper handling, dosage, and adverse reactions, as well as injections for difficult studies (Chetlen et al., 2015). Given the nature of CT and MRI, there are many computer-based simulators for these procedures, especially thoracic studies. "An anthropomorphic moving heart phantom is now available and has been used to assess functional cardiac parameters with MRI, multidetector, and dual-source CT" (Chetlen et al., 2015). Interpersonal skills can also be honed using virtual simulation for radiographic sciences.

Non-Procedural Skills Training

Image Interpretation

Virtual simulation is an exciting new tool for training medical students to interpret radiologic images. "The [virtual] workstation allows student manipulation and interpretation of entire imaging studies in a way that closely mirrors the clinical practice of radiology and supplements the educational approaches of didactic lectures and reading room observation" (Strickland, Lowry, Petersen, & Jesse, 2015, p. w290). Radiology simulators have been developed for residents prior to taking overnight call in the emergency department focused on Digital Imaging and Communications in Medicine (DICOM) and Picture Archiving and Communication System (PACS) training since radiologists are not generally on-campus during this shift (Ganguli et al., 2006; Towbin, Paterson, & Chang, 2008). Along these lines, the American College of Radiology (ACR) has created a cloud-based PACS called Radiology Content Management System providing virtual teaching files that can be used collaboratively throughout multiple institutions (Chetlen et al., 2015).

Professionalism and Communication

Communication is an important part of any healthcare department, but especially in radiology. Radiologists and technologists need to know how to communicate effectively, but most do not receive any formal training for this while in school (Chetlen et al., 2015; Klein & Neal, 2016). Virtual patients can be used to simulate situations for scenarios such as obtaining informed consent, discussing an error during a procedure, disclosing bad news, sharing results with an ordering physician, or determining the appropriate test to order. These patients can be programmed to experience various responses such as anger, disbelief, shock, guilt, and denial (Chetlen et al., 2015). This type of training can not only improve communication skills, but also increase empathy and attitudes toward patients and families. Simulation actives can be used to develop effective communication and collaboration in interprofessional health care teams (Shanahan, 2016a; Lemheney et al., 2016). Finally, the use of virtual simulation specific to RS education should be explored to help increase students' technical skills before interacting with patients.

Training for Radiographic Science Students

Studies have shown how using virtual simulated health care experiences can improve student performance in a clinical setting. Ahlqvist et al. (2013) developed a virtual simulator for radiographic examinations. The researchers compared student performance in the assessment of radiographic image quality after training with a convention manikin or with the virtual radiography simulator. Through a linear mixed-effect analysis, they found a statistically significant difference between the experimental and control groups regarding proficiency change and concluded "there are indications that the virtual radiography simulator training can reduce tutor time and the time needed for training in the radiography [clinical setting]" (Ahlqvist et al., 2013, p. 387).

In a meta-analysis of articles which compared simulation versus other instructional methods, Cook et al., (2012) agreed with Ahlqvist et al. (2013), stating virtual simulation training is associated with higher learning outcomes. Cook et al. (2012) did caution, however, that their study could not address the costs, procedure of aligning simulation with educational objectives, or the method with which simulation is effectively integrated and that these factors would influence simulation's association with higher learning outcomes. Kong et al. (2015) studied students' knowledge acquisition after virtual simulation learning activities using pre- and post-tests. Their conclusions were similar to the previously mentioned studies, but had some additional conclusions which seemed to contradict some of their findings. While pre- and post-test indicated both that the students learned and the students perceived their confidence and positioning skills increased, the test results showed students perceived simulations did not help improve decision-making skills. Both Cook et al. (2012) and Kong et al. (2015) stated the need for future research to explore virtual simulation's role in developing critical-thinking skills and in the best methods of integrating simulation in established curriculum to align with educational objectives and goals.

Current Studies in Radiographic Science

Though there is currently a paucity of literature available on preparing students to enter the clinical setting as it directly relates to RS, some researchers have attempted to evaluate the effect of virtual simulation on students' clinical preparedness. Understanding the gaps in available empirical knowledge and assessing research attempts to fill that gap can help future researchers know what to study and how to better approach their research methods.

In an attempt to gather information about the use of virtual simulation in RS, Thoirs, Giles, and Barber (2011) performed a literature review as well as surveyed and interviewed stakeholders of a medical radiation sciences program in Australia. They found Virtual Radiography™ (Shaderware, UK), a virtual radiography simulation system, was being used in the United Kingdom. Based on an interview of an academic using the virtual simulation program, student feedback was positive and the program supported acceleration of student skill level, better preparing them for clinical placement.

Encouraged by this information and two papers published by Shaderware (Cosson & Willis, 2012a; Cosson & Willis, 2012b), Shanahan (2016a) developed a pilot study to use Projection VR™ (a simulation program within Virtual Radiography™ suite) as an educational tool in the laboratory component within an Australian RS program. The virtual simulation program was used in addition to traditional simulation practices. The researcher found an increase in students' self-efficacy scores and confidence level when setting up radiographic procedures. Increasing student confidence level in fundamental elements of radiography exams before students enter the clinical setting can make the transition from the university to the clinical practice less stressful for students (Mason, 2016; Shanahan, 2016a). With these elements enhanced before students enter the clinical setting, students can use time in the clinical setting to focus on experiences and skills that can only be gained in the clinical setting, such as patient interaction skills (Bridge et al., 2016; Shanahan, 2016a).

Another pilot study of an established software was conducted by Wagner (2017) using the program SIMTICS with a group of undergraduate RS students in their final didactic semester before entering the clinical setting. SIMTICS is a computer software offering students an opportunity to practice positioning and all other elements of taking an X-ray using a virtual patient. Wagner (2017) wanted to use this to complement the limited hands-on lab time the students had to determine if it would increase their competence. The students that participated in the study did not complete the entire study as the investigator had hoped due to frustration with the program itself. While the program itself had potential and the students saw merit in it, there were many shortcomings, such as sensitivity of the program, inability to continue when mistakes were made, and limited study availability (Wagner, 2017).

Dikshit, Wu, Wu, and Zhao (2005) and Papamichail, Pantelis, Papagiannis, Karaiskos, and Georgiou (2014) developed their own simulation software to pilot with students. Dikshit et al. (2005) created a virtual simulation program using animated simulations for multiple modalities: X-ray, CT, MRI, ultrasound, and positron emission tomography (PET) to fill a need for biomedical engineering students. In their program, students were provided with text information, web page links, animations, simulations, and online homework about imaging principles for each modality. The result was a diagnostic image where students could see the principles applied. At the time of publication, the program was being tested to determine if there was an increase in student comprehension of the concepts presented in the program, but no results were provided. Papamichail et al. (2014) developed an open access web-based educational platform with simulation and self-assessment features to teach medical students, radiology residents, physicists, and biomedical engineers about medical image reconstruction and processing. A preliminary evaluation of the program was performed by 46 medical students using a five-point Likert-type scale. Overall, the content of the course was considered effective, well structured, and relevant; however, the students found it would make a better supplement to lecture content rather than a stand-alone tool (Papamichail et al., 2014).

These current radiography simulation studies are pilot studies intended to demonstrate proof of concept for incorporating virtual simulation in RS education.

Further, longitudinal research studies are needed to truly evaluate the use of virtual simulation in RS education, effective pedagogical characteristics of the simulation program, and the proper methods to implement such technologies in RS educational programs. Current research studies can help inform future researchers as to more effective methods of study and implementation techniques.

Future Directions and Research

As technology throughout the world continues to develop and advance, so too does innovations in simulation. The simulation methods discussed thus far, both real-life and virtual, are constantly being adapted to medical education. Since future students will have exposure to and experience with new and advancing technologies, these technologies should be adapted to educational use. Using these technologies in an educational setting is important because it uses tools and methods with which students are already familiar and have used in daily practice (Wertz, Hobbs, & Mickelsen, 2013). The challenge will be their proper implementation into radiographic science education. Few studies have specifically evaluated the role of simulation, specifically virtual simulation, in RS education. Those which have addressed this specific challenge all identify proper adaptation and integration of simulation technologies into existing curriculum. These studies also express the importance of aligning such adaptations with measurable educational objectives, stating simulation should seek to support, not replace current educational practices (Cook et al., 2012; Kong et al., 2015; Tjiam et al., 2014). Future research should seek to explore the best methods of integrating simulation in established curriculum to align with educational objectives and goals.

Though educational pedagogy and curricular adaptation are the most commonly identified areas for future research, the literature also identifies a number of other ideas. With the innovation and development of augmented and mixed reality technologies, more and unique opportunities are available in RS education. Augmented reality overlays used during a patient exam can provide real-time information to the radiographer, such as body part thickness, skeletal anatomy, relative positioning, and patient motion (MacDougall, Scherrer, & Don, 2018). Simulation actives can be used to develop effective communication and collaboration in interprofessional health care teams (Lemheney et al., 2016; Shanahan, 2016a). In addition, this type of educational experience can be used to increased empathy and favorable attitudes towards patients and families (Chetlen et al., 2015). Varied and personalized simulation experience can help students develop critical thinking skills in a safe learning environment (Holmström & Ahonen, 2016; Marshall & Harris, 2000; Sedden & Clark, 2016). Virtual simulation offers a method of assessment free of personal bias or evaluator influence (Berry et al., 2007; Sabir et al., 2014). All these identified benefits of simulation lack sufficient empirical research, warranting future research to focus on these areas.

Chapter Summary

Students in RS education programs must master the both the didactic education and psychomotor skills necessary to perform radiographic examinations on patients in a clinical setting. Simulation is the most common method of helping RS students prepare to perform such examinations. Simulation can be performed either in live or virtual environments. Recently there has been a trend to adopt virtual simulation in medical education because of the reduced adverse effects virtual simulation provides as opposed to live simulation and real-world practice. Though there is a paucity of literature available discussing virtual simulation's use in RS education, recent studies in this field and related medical imaging modalities have shown the benefits of using virtual simulation. The purpose of this study was to investigate students' perceptions of their own self-efficacy and positioning skills after using a virtual radiography simulation in an undergraduate course.

RS students must complete a series of competence exams as part of their clinical education. They must meet ARRT criteria for these exams under the supervision of a registered radiologic technologist. Students must be prepared in the didactic and laboratory setting before they are ready to perform radiographic exams on real patients. Simulation is the most common practice for preparing RS students to enter the clinical setting. Studies have shown how psychomotor skills can be improved in a simulated environment and those skills can also translate to the clinical environment. Virtual simulation is a new educational tool which has the potential to help supplement deficiencies in traditional simulation such as demands for time, space, and equipment. Simulation is particularly suited to the unique needs of adult learners: self-pacing and the ability for repetition, real-time and learner-controlled feedback, and on-demand accessibility to education at the convenience of the learner. Learning theories used in RS education leverage these attributes by building on previous knowledge, applying abstract knowledge to real-life scenarios, distributing practice, and increasing self-efficacy. Few studies have researched the effectiveness of implementing virtual simulation into an existing RS positioning curriculum.

CHAPTER THREE: METHODOLOGY

The purpose of this study was to investigate students' perceptions of their own self-efficacy and positioning skills after using a virtual radiography simulation in an undergraduate course. Studying the effect of implementing virtual simulation in a radiographic education curriculum will help radiographic science (RS) programs understand the role virtual simulation has in preparing students to enter the clinical setting. This understanding can then be used to help other radiography programs.

The study's design of mixed methods research (MMR) following explanatory sequential research (ESR) involved collecting quantitative data first and then explaining the quantitative results through in-depth qualitative data. Activity Theory (AT) served as a theoretical framework for this study. AT provides a theoretical framework by which the effectiveness of implementing a tool, such as a simulation program, can be evaluated. The various components of AT interact in a system of combined constructs. By looking at the interactions between and among constructs, researchers can dissect how and in what ways a tool is being used and if the method of use is effective in achieving the desired outcome.

In the first, quantitative phase of the study, Likert scale survey data was collected from first year radiography students at a four-year institution in the intermountain West. Using Activity Theory, the survey assessed whether virtual radiography simulation influenced students' perceived self-efficacy and clinical competency related to radiographic positioning skills. The second, qualitative phase used the same AT tenets as a follow-up to the quantitative results to help explain extremes of high and low results in the survey data. In this exploratory follow-up, the plan was to explore student perceptions of their own self-efficacy and positioning skills after using the virtual radiography simulation program with 8 first year radiography students who represent the high and low quantitative data.

In this chapter, I restate and expound upon the study's research questions, explain the research methodology and design, and describe how subjects will participate in the study. I also describe the sources of data, how the data was collected, and how the data was be analyzed. A discussion of the ethical considerations and the limitations and delimitations of the study is included at the end of the chapter.

Statement of the Problem

By the end of RS educational programs, students must demonstrate competence in performing all required radiographic examinations in a safe and proficient manner. When students start the RS program, they have no previous experience and are often hesitant or unsure when working with patients. In medical imaging, when students are hesitant or lack knowledge and skills they are prone to produce images with decreased quality or expose patients to unnecessarily high amounts of radiation (Ortiz, 2015). Comfort, familiarity, and skills are acquired with time and practice, but these are experiences new RS students do not have. Research suggests RS students benefit from the opportunity to practice radiographic examinations in a simulated environment prior to demonstrating that competence on real patients in the clinical setting (Ahlqvist et al., 2013; Berry et al., 2007; Cook et al., 2012; Gordon et al., 2004; Kasprzak, 2016; Kong et al., 2015; Shanahan, 2016a; Wright et al., 2006).

To prepare students for the clinical setting, RS program faculty and CIs must find ways to develop student clinical competence. Competence is both a measurement of and an indicator for student clinical preparedness (Castillo et al., 2011; Clarke & Holmes, 2007; Williams & Berry, 1999). The goal of radiographic science education programs is to prepare students to perform radiographic examinations on real patients in hospitals and clinics. RS programs should establish a way to improve students' competence in terms of radiographic examinations as part of preparing students (i.e. competence, comfort, and confidence) to enter a clinical setting.

Research Questions

Simulation is a vital tool in healthcare education and is frequently used in many health care-based educational programs. Radiography educators must ascertain if simulation techniques have an impact on students' preparedness to enter the clinical setting, and why techniques do or do not have an impact. The overall focus of this study was to investigate students' perceptions of their own self-efficacy and positioning skills (i.e. clinical readiness) after using a virtual radiography simulation. These two areas of study (i.e. self-efficacy and positioning skills) were investigated using an ESR mixed methods design.

To investigate students' perceptions of their own self-efficacy and positioning skills after using a virtual radiography simulation, the following research questions were developed. The research questions were further explored in phases of analysis follow a mixed-methods ESR design, with Phase 1 being quantitative and Phase 2 being qualitative.

Q1. What do students report as to their own self-efficacy and positioning skills after using a virtual radiography simulation program?

Q2. What are students' perceptions of their own self-efficacy and positioning skills after using the virtual radiography simulation program?

Research question 1 (RQ1) investigates students self-reported scores through a Likert scale survey instrument based on Shanahan (2016b). RQ1 is the quantitative phase of this mixed-methods study. Research question 2 (RQ2) seeks to explore students perceptions through interviews to explain the results of the quantitative data. RQ2 is the qualitative part of this mixed-methods study.

Normal laboratory practice time is dedicated each week for students to practice radiographic positioning based on what they were learning in the didactic positioning course. Each lab session lasts for 2 hours. Students were given the virtual radiography simulation program to use at home on their own time. Students were asked to use the simulation program at home for at least 1 hour each week. One hour was chosen because students already have 2 hours of in-person positioning practice; it was expected that an additional hour of virtual practice would be enough time for students to see benefit to using the virtual simulation thought being too much burden to make students reluctant to comply or negatively affect their perceptions of using the simulation program. Students were told they could use the simulation program however they wished, but were encouraged to use it along with their studies for the week and in conjunction with their didactic class and laboratory session material.

Given the important role of simulation in RS education, Engeström's (2001) model of learning mediated by tools (a.k.a. Activity Theory) was used as a theoretical framework to analyze the implementation of virtual simulation in the curriculum.

1) Student – Tool
    a. Did students like using the tool?
    b. Did students find the software easy to use?
    c. Did technical problems make using the tool difficult for students?
2) Rule – Student – Tool
    a. How much time did students use the tool each week?
    b. Does use time have a relationship with reported enhanced skill or confidence?
3) Student – Tool – Outcome
    a. Did students report enhanced skill or confidence? If so, which skills or how in confidence?
4) Student – Community – Tool
    a. Did students prefer to use the tool as an individual or collaborative learning activity?
5) Division of Labor – Student – Tool
    a. Did the software program provide enough instruction/administration to make it a valuable, self-regulated learning tool?

These AT components were further broken down and addressed in the survey instrument.

Research Methodology

Due to a lack of experience conducting MMR studies, it was proposed to use a fixed-methods design and a typology-based approach. The use of qualitative and quantitative methods were decided from the onset of the study with the caveat that challenges when conducting the study might necessitate some adaptation. The design for this study is the ESR design (Creswell, 2014; Creswell & Plano Clark, 2018). In an ESR design the researcher collects quantitative data and then qualitative data to help explain the quantitative results (see Figure 3).

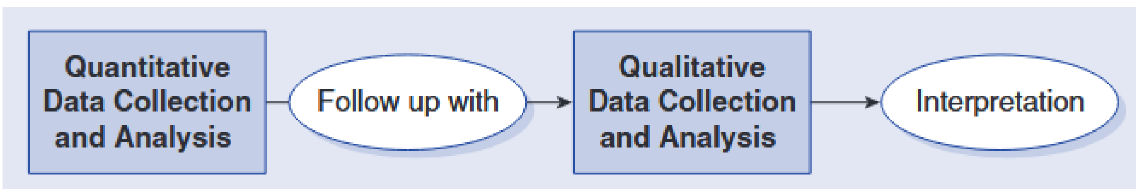

Figure 3. Explanatory Research Design. Creswell & Plano-Clark (2010)

Other studies using virtual simulation to improve clinical readiness and performance serve as a model for the design of this study. Specifically, Shanahan's (2016b) research provided a template for applying AT to the proposed intervention.

This study was best suited to an MMR approach because it sought to understand how incorporating virtual simulation in the current curriculum affects RS students' competence and preparedness to enter the clinical setting (i.e. perform radiographic exams on real patients). The idea of clinical readiness or translation of psychomotor skills is not easily quantifiable, though quantitative methods such as surveys can gather relevant data. The topic is also not specific to qualitative research, though interviews with the participants can give valuable insight. The research study benefited more from combining quantitative and qualitative techniques than from performing each individually.

Currently in the RS program, simulation is used for both learning and assessment. Simulation as assessment is a recent addition to the RS program and has been given positive feedback from students, faculty, and CIs. However, some students feel the time taken for laboratory testing (i.e. simulation as assessment) has taken away time from laboratory instruction and practice (i.e. simulation as learning). Students prefer simulation for learning rather than assessment, so this study focuses only on simulation's use in instruction. It explores the perceived effect of implementing additional virtual simulation to assess students' feelings of preparedness to enter the clinical setting.

Research Design

This research sought to investigate students' perceptions of their own clinical preparedness after using a virtual radiography simulation. Therefore, the primary construct for survey administered to the research participants was clinical preparedness. The dimensions for this survey included the demonstration of psychomotor skills required to perform radiographic examinations (competence) and students' self-evaluation of preparedness to perform exams in the clinical setting (self-efficacy). Therefore, the latent constructs for this survey were competence and self-efficacy.

Competence is a measure of a student's technical radiographic skill in performing a radiographic examination (ARRT, 2016; Castillo et al., 2011). Criteria used to evaluate competence include patient positioning, part positioning, knowledge of X-ray equipment manipulation, radiographic exposure technique, central ray alignment, central point alignment, source to image receptor distance, and image receptor placement. These psychomotor skills are required to perform radiographic exams and produce diagnostic-quality images (Castillo et al., 2011; Tolley Gurley & Callaway, 2011).

Self-efficacy refers to a student's perception and evaluation of their own ability and skills. "Self-efficacy refers to beliefs in one's capability to organize and execute the course of action required to produce given attainments" (Bandura, 1997, p. 3). Self-efficacy is how a person perceives their own ability to accomplish a goal, relating only to a particular subject or activity. This differs from self-esteem, which is confidence in one's own worth or abilities (Bandura, 1997; Kitching et al., 2011). Higher levels of self-efficacy tend to be tied to higher performance (Bandura, 1997; Kitching et al., 2011). Students with higher self-efficacy tend to perform radiographic exams with more confidence and better outcomes.

Table 2 summarizes how the research questions for the study, the methods for data collection, and the methods for data analysis align in this study. All of these elements of the study will be elaborated in the sections that follow.

Table 2. Study's Alignment to Research Questions and Methodology

Problem	Research Questions	Data Collection and Sample	Analysis and Expected Results	Answering the Research Question
Radiographic Science students being prepared to perform exams on patients. Two major factor: self-efficacy and competency. Based on the literature, simulation addressed/helps these concerns. The benefits of virtual simulation can provide more flexibility and opportunity when time and resources are limited. Mixed Methods Explanatory sequential Design	Quantitative: What do students report as to their own self-efficacy and positioning skills after using a virtual radiography simulation program?	Likert survey based on Activity Theory constructs and survey performed by Shanahan (2016b). 1st year radiography students in the RS 3310 course (n=13)	Descriptive statistics: mean, median, standard deviation, and interquartile range. Bar, pie, and scatterplot charts can show unique or unusual cases. Results expected to be favorable self-reported self-efficacy and positioning scores after using the virtual simulation.	Descriptive statistics will show trends in how students report their self-efficacy and positioning skills after using the simulation program through the lens of Activity Theory.
	Qualitative: What are students' perceptions of the own self-efficacy and positioning skills after using the virtual radiography simulation program?	Interviews with 2 student cohorts representing the extremes of the survey data: 4 students with the highest perception score, and 4 students with the lowest perception scores. Questions based on Activity Theory and themes found in the quantitative data: "collection related to statistically significant results, statistically nonsignificant	Coding of interviews and identification of common themes. Two phases of coding: descriptive coding and focused coding. Findings expected to explain the favorable self-reported survey scores.	Common themes identified will help explain how students perceived their own self-efficacy and positioning skills after using the simulation program through the lens of Activity Theory.

		results, key significant predictors, variables that distinguish groups, outlier or extreme results, or distinguishing demographic characteristics" (Creswell & Plano-Clark, 2018) through the lens Activity Theory		

Participants

The participants of this study were 1st year RS students at a four-year institution in the intermountain West. Specifically these students were those recently accepted into the RS program (i.e. RS students) and not those seeking admittance into the program (i.e. pre-RS students). The cohort consisted of 21 students and all were given voluntary access to the virtual simulation program; however, only 13 students participated in the survey. Therefore the sample size is 13 (n=13). The participants in the sample were chosen based on a convenience sampling. Convenience sampling was used because the researcher had access to these students (i.e.1st year radiography students at the university), the students were using the simulation in their didactic course during the time of the study, and these students were willing and available to be studied (Creswell, 2014).

The RS program at this specific institution was a baccalaureate program, which is atypical for an entry-level program in RS; most RS programs in the United States are three year associate degree programs. The difference between the two degrees is baccalaureate programs must generally complete two years of general education prerequisite coursework while associate programs generally only complete one year of prerequisite coursework. RS students complete two years of prerequisite general education coursework and then two years of programmatic coursework specific to RS. Therefore, participants in this study may not be representative of the larger population of RS students in the United States.

Students are accepted into the RS program at the end of the Spring semester each year and start the RS program in the following Fall semester. Selection of students into the RS program is based on the grades students earn in the prerequisite courses. Each grade is assigned a point value (i.e. an "A" is worth 4 points, a "B" is worth 3 points, a "C" is worth 2 points, and a "D" is worth 1 point). The point value for each class is then multiplied by how many credits were earned for passing the class. The total points earned for each prerequisite class are added together; this composite score is then multiplied by the student's GPA of the prerequisite classes. Applicants to the RS program are ranked based on this total score. The top 30 ranked applicants are put through an interview process and are evaluated by a panel of 6 interviewers based on a set of pre-established questions. Each applicant's interview score is the average of the scores received from among the interviewers; the average interview score is added to the applicant's composite grade score to give the applicant an overall score. The applicants are then ranked based on this overall composite score (i.e. grade score plus interview score), and the top 21 students are offered admittance into the RS program. Therefore, the students accepted into the RS program each year demonstrate high academic achievement and interpersonal communication skills.

Each cohort consists of 21 undergraduate students. Most of these students are considered traditional college students in that they entered college shortly after completing high school and are pursuing their 1st degree. However, each cohort generally has some non-traditional students, students who either have a prior college degree, who are older than traditional college students (i.e. 25+ years old), or who are pursuing a second career.

Data Collection

First-year RS students were invited to participate in the study. In this MMR study, the first phase was the quantitative part. Quantitative data was collected from the students in the form of a Likert scale questionnaire centered on the students' perception of skill acquisition and clinical readiness in relation to the tenets of AT. Survey items were based on those in Shanahan's (2016b) survey instrument, because Shanahan's research questions and methods were similar to those of this study. Shanahan is assumed to have developed that survey instrument, which is not found in any other research or published venue. Shanahan did not respond to inquiries into the origin of the instrument. Interestingly, many of the survey items are similar to those in the instrument developed by Kitching et al. (2011). It is not known if there is any relationship between the two survey instruments. For the purposes of the current study, the instrument used by Shanahan was solely attributed to Shanahan.

Items from Shanahan's (2016b) survey instrument were adapted to the current research study. Shanahan used a different virtual simulation software program (i.e. ProjectionVR), so survey items were reworded to use the name of the virtual simulation software program that will be used in the current study (i.e. MedspaceXR). In addition, Shanahan used the virtual simulation software as part of scheduled laboratory practice time, whereas in the current study students used virtual simulation outside of scheduled laboratory practice time. Therefore, the wording of this item was adapted to reflect the simulation use in this study. Lastly, Shanahan used virtual simulation as a teacher-led activity. The current research study had students use the simulation program as a student-led activity, relying on instruction received in class to guide simulation use, so this item was also adapted to reflect the current study.

As shown in Table 3, the survey items were scored on a 5-point Likert scale (5-strongly agree, 4-agree, 3-neither agree nor disagree, 2-disagree, 1-strongly disagree).

The scores indicated to what degree the students agree or disagree with each statement in relation to using the virtual simulation positioning program. The exceptions were the second section (Rule – Student – Tool), which allowed students to enter the amount of time spent with the software, and the fourth section (Student – Community – Tool), in which students selected one of three options describing their learning preferences. The survey instrument also contained items about participant demographic information such as gender, age, and race. The instrument acquired data from identified constructs of AT, but focused on 2 overall areas of evaluation for the Student – Tool – Outcome (STO) construct: student competence and student self-efficacy.

Table 3. Survey Instrument's Alignment to Activity Theory

Activity Theory Interaction	**Survey Instrument Criterion**
Student – Tool	1. I liked using MedspaceXR 2. MedspaceXR is easy to use 3. Technical problems made using MedspaceXR difficult
Rule – Student – Tool	1. On average how much time did you spend using MedspaceXR each week?
Student – Tool – Outcome	Student Competence 1. Enhanced my routine procedure for setting up radiographic examinations 2. Allowed me to quickly see images and understand if changes needed to be made 3. Enhanced my image evaluation skills 4. Helped me become more fluent or systematic in a radiographic examination e.g. not repeating steps 5. Helped me learn as I was able to repeat activities until I was satisfied with the results 6. Had a positive effect on my ability to set up a radiographic examination 7. Had a positive effect on my ability to evaluate radiographic images
	Student Self-Efficacy 1. Had a positive effect on my confidence level in setting up radiographic examinations 2. Had a positive effect on my confidence level in evaluating radiographic images

	3. Had a positive effect on my ability to self-evaluate when I set up radiographic examinations 4. Had a positive effect on my ability to self-evaluate when I evaluate radiographic images 5. Encouraged me to think more about radiographic procedures 6. Encouraged me to think more about evaluating radiographic images 7. Encouraged me to solve problems
Student – Community – Tool	1. I learn best with MedspaceXR when it is an individual activity (I used MedspaceXR on my own) 2. I learn best with MedspaceXR when it is a shared activity (I used MedspaceXR with 1 or 2 other students) 3. I learn best with MedspaceXR when it is both/either an individual or shared learning activity
Division of Labor – Student – Tool	1. MedspaceXR was designed to help guide me through positioning activities 2. The MedspaceXR reference guide was a valuable tool in helping me use the VR program 3. I relied on other students to help me learn using MedspaceXR

The second phase of this MMR study was the qualitative part. Data for this phase were collected from interviews. Individual interviews with the participants gave the students opportunity to share formative feedback and identify barriers to the success of the intervention as well as help to explain the results found from the quantitative survey. Purposeful sampling was used to recruit students to participate in individual interviews. Purposeful sampling is a sampling method where the researcher intentionally selects participants who have experienced the key concept being explored in the study (Creswell & Plano-Clark, 2018). That is, in explanatory sequential research (ESR) the sample for qualitative explanation comes from the participants in the quantitative phase. Extreme case sampling is used when one is interested in learning about particularly successful or unsuccessful cases (Creswell & Plano-Clark, 2018). In this study, extreme cases were defined as students who reported exceptionally high or low self-efficacy and competency scores.

The number of interview participants for a qualitative study is dependent on the type of study being performed as well as the assurance that a sufficient amount of information has been collected to develop an accurate and representative understanding of the data (i.e. saturation) (Creswell & Plano-Clark, 2018; Collins, 2010). Creswell (2014) recommends 3-5 participants as a sample size for explanatory sequential research. To achieve saturation, a researcher collects and analyzes qualitative data to the point where sampling additional cases does not uncover any additional themes or codes (Glaser & Strauss, 1967; Lincoln & Guba, 1985; Sandelowski, 1995). Therefore, to analyze extreme cases in this study, participants whose average score on the STO criterion represent the 4 highest scores and the 4 lowest scores were selected for interviews. If new themes or codes continued to emerge from the 4 participants in each of the low and high categories, additional participants would have been recruited until saturation had been reached. Ultimately, saturation was reached within the 4 participants of each group.

Questions for the interviews were developed from results of the student survey by identifying common themes in the quantitative data. Following Engeström's (2001) model of learning mediated by tools theoretical framework, the following served as an initial protocol for the semi-structured interviews:

1) Student – Tool
    a. How did you like using the simulation program?
    b. How easy did you find the software to use?
    c. What kind of technical problems or other barriers made using the tool difficult?

d. What do you believe are the benefits of using this simulation program?

e. What do you believe are the limitations of this simulation program?

2) Rule – Student – Tool

a. How much time did you use the tool each week?

b. How do you feel the amount of time you spent using the software affected your self-confidence?

c. How do you feel the amount of time you spent using the software affected your clinical skills?

3) Student – Tool – Outcome

a. How do you feel the simulation program affected your self-confidence?

b. How do you feel the simulation program affected your clinical skills?

4) Student – Community – Tool

a. In what ways did you use the simulation program by yourself?

b. In what ways did you use the simulation program with others?

5) Division of Labor – Student – Tool

a. Did the software program provide enough instruction/administration to make it a valuable self-regulated learning tool?

b. How did using what you learned in class affect your ability to use the simulation program?

The quantitative statistical results in Phase 1 directed the follow-up sampling procedure of selecting the participants best able to help explain the extremes found in the quantitative data (Creswell & Plano-Clark, 2018). Respondents with the 4 highest self-reported scores and respondents with the 4 lowest self-reported scores were invited to attend interviews. All 8 students accepted the invitation to participate in the interviews. Invitations were extended via an email explaining the nature of the interview along with the time and place of the interview. The interview sessions were audio recorded, and the interviewer took notes during the interview. The notes and audio recordings were transcribed and kept in password-protected cloud storage. The transcribed interviews and notes were coded to identify common themes among the qualitative data.

As Creswell and Plano-Clark (2018) suggested, questions for the interviews with students were based on themes found in the quantitative data, such as: “collection related to statistically significant results, statistically nonsignificant results, key significant predictors, variables that distinguish groups, outlier or extreme results, or distinguishing demographic characteristics” (p. 250).

Data Analysis

Descriptive quantitative data from the surveys was evaluated to identify trends among the respondents and see if a relationship exists between the intervention and clinical preparedness through the lens of student self-perceptions. Given the small cohort size (n=13), only descriptive statistics were used for analysis of the survey data

(Shanahan, 2016b). Such descriptive statistics included frequency, mean, median, standard deviation, and interquartile range.

To answer the research question, individual descriptive statistics scores for each of item on the survey instrument as well as composite descriptive statistics scores for each interaction in AT (e.g. Student-Tool) were calculated. Also, composite descriptive statistics scores of each interaction in AT (i.e. Student – Tool, Rule – Student – Tool, Student – Tool – Outcome, Student – Community – Tool, and Division of Labor – Student – Tool) were calculated. Tables of the aggregate data, both for individual survey criterion as well as for categories of AT interaction, was used to display and analyze the descriptive data. Bar, pie, and scatterplot charts were used as necessary to further demonstrate unique or unusual findings in the descriptive statistics. To analyze extreme cases for further qualitative analysis, participants whose average score on the STO interaction represent the four highest scores and the four lowest scores were selected for interviews.

Qualitative data gathered during interviews was coded and evaluated for themes related to the perceived effect of the intervention on clinical performance. Coding is a process that permits data to be "segregated, grouped, regrouped and relinked in order to consolidate meaning and explanation" (Grbich, 2007, p. 21). Analysis of codes, then, is to search for patterns in data and for ideas that help explain why those patterns exist (Bernard, 2006). The qualitative coding software NVivo was used to help analyze the data for codes and themes as well as to keep track of coding categories across various sources of qualitative data (i.e. interviews).

To get a full understanding of qualitative data and thoroughly process the information, Saldaña (2016) recommended a process of recoding and recategorizing, which the author calls First Cycle Coding and Second Cycle Coding. The first cycle coding used in this research was *descriptive coding*. Descriptive coding summarizes in a word or phrase the overall topic of a passage of qualitative data (Saldaña, 2016). Descriptive coding is appropriate for almost all qualitative studies and particularly suited to novice qualitative researchers learning to code a wide variety of data sources (Saldaña, 2016). Codes for this cycle included commonly repeated ideas or themes from the interviews.

The second cycle coding used in this research was *focused coding*. Focused coding seeks the most frequent or significant codes from the first cycle coding to develop the most pertinent categories and "requires decisions about which initial codes make the most analytic sense" (Charmaz, 2006, p. 57). Focused coding is appropriate for almost all qualitative studies but particularly for the development of major categories or themes from the data (Saldaña, 2016). Codes for this cycle created categories for the codes and themes collected in the first cycle.

Ethical Considerations

Informed consent was obtained from all participants prior to the beginning of the research study. Students were informed they had the right to refuse participation in the study, refuse to answer any questions (either in part or in full) at any time during the study, or stop participating in the study at any time without consequences or repercussions. Student participation or declination of participation had no positive or negative affect on any of their grades or standing in the RS Program. All participation with the virtual radiography positioning software was voluntary; no elements of participation were required as part of course requirements. The survey took approximately 15 minutes or less to complete the survey and approximately 30 minutes to complete each individual interview.

There was no anticipated risk to participants in the study. Students who participated in the study continued to use established educational techniques and methods already implemented in the RS program. This study did not replace any educational components or delivery methods currently implemented in the RS program. Survey and interview participants were reminded that their responses were kept confidential. Survey data was anonymized and kept secure by using password protected cloud storage and/or a password protected computer. Qualitative data was assigned categorical labels for anonymity, and the data was kept secure in the same manner as the survey data. Survey instruments, notes, and transcribed tapes were stored in a locked and secure location.

Chapter Summary

This research study sought to investigate the impact implementing a virtual radiographic positioning simulation software program had on students' perceptions of their own clinical preparedness (i.e. competence and self-efficacy). The research questions were investigated through an ESR mixed methods design. The first phase consisted of the quantitative phase that involved data collected through a survey instrument designed to use AT as a theoretical framework. The second phase of the study was the qualitative phase where data was collected from semi-structured interviews with students representing the highest and lowest scores on the survey instrument. Questions for the interviews were based on themes collected in the first phase. There was no anticipated risk to participants in the study. It was anticipated that students would have overall high scores on the survey and positive feedback in the interviews in regards to their competence and self-efficacy in clinical preparedness because of the virtual simulation program.

CHAPTER FOUR: RESULTS

The purpose of this study was to investigate students' perceptions of their own self-efficacy and positioning skills after using a virtual radiography simulation in an undergraduate course. Analysis of students' self-efficacy and positioning skills was based on self-reported perceptions collected through a survey instrument and follow-up interviews. Research methodology for this study followed an explanatory sequential research (ESR) design in a mixed methods research (MMR) model (Creswell & Plano-Clark, 2018). The following research questions were used to guide the collection and subsequent analysis of the data:

Q1. What do students report as to their own self-efficacy and positioning skills after using a virtual radiography simulation program?

Q2. What are students' perceptions of their own self-efficacy and positioning skills after using the virtual radiography simulation program?

Research question 1 (RQ1) investigates students self-reported scores through a Likert scale survey instrument based on Shanahan (2016b). RQ1 is the quantitative phase of this mixed-methods study. Research question 2 (RQ2) seeks to explore students perceptions through interviews to explain the results of the quantitative data. RQ2 is the qualitative part of this mixed-methods study.

This chapter includes a description of the virtual simulation used for the study, discusses the characteristics of the research participants, and reports the findings and results of the data analysis to answer the research questions listed above. Research question 1 (Q1) was investigated using a survey instrument adapted from Shanahan (2016b) and based in the tenets of Activity Theory (AT). Research question 2 (Q2) further explored students' self-reported survey scores through interviews.

AT provides a theoretical framework by which the effectiveness of implementing a tool, such as a simulation program, can be studied. The various components of AT interact in a system of combined constructs. By looking at the interactions between and among constructs, researchers can dissect how and in what ways a tool is being used and if the method of use is effective in achieving the desired outcome (Hasan & Kazlauskas, 2014; Hashim & Jones, 2007; Issroff & Scanlon, 2002). According to Shanahan (2016b), the representation of activities through Activity Theory considers participants and tools or resources present in an activity, as well as the context within which the activity occurs. The benefit of using an AT framework, according to Issroff & Scanlon (2002), is that it forces consideration of a range of factors which impact on the use of technology in higher education. This approach supports gathering user feedback beyond student reaction to, or satisfaction with, the tool (Weller et al., 2012) to include a broader range of factors in the evaluation.

The following 5 interactions were chosen as the framework of analysis because each incorporates how the student interacted with the tool to achieve the outcome: Student – Tool; Rule – Student – Tool; Student – Tool – Outcome; Student – Community – Tool; Division of Labor – Student – Tool. These interactions investigate not only how the student uses tool (i.e. simulation program), but also incorporates the interaction towards the desired outcome. The students experience with the tool as it relates to other factors (i.e. rule, community, and division of labor) help give context to how the student interacted with and used the tool, besides the students' satisfaction or personal preference with the tool. This same framework of analysis was also used by Shanahan (2016b), one of the studies upon this research project was based. Within each of the subsections of this chapter the emergent themes in relation to the 5 interactions of AT (see Figure 4) will be highlighted and described.

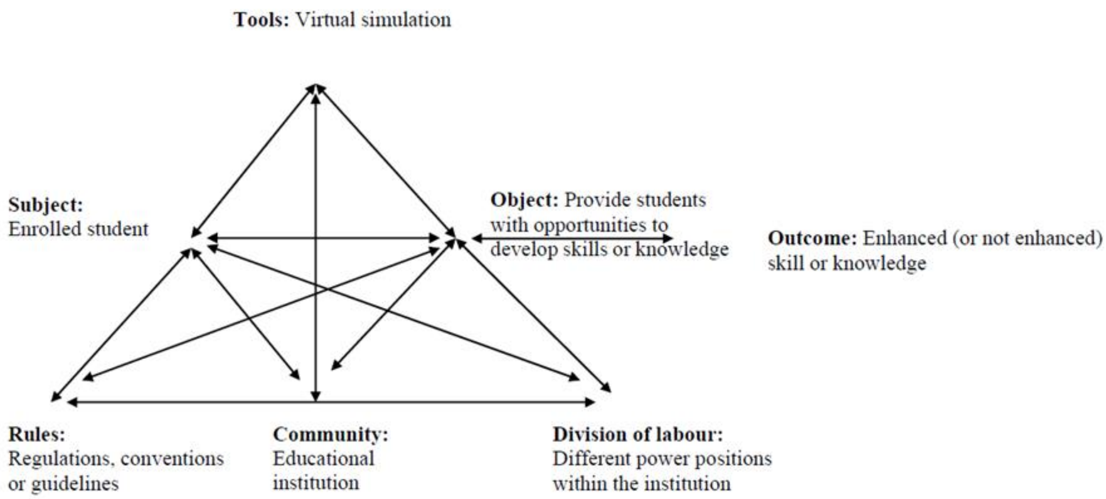

Figure 4. Activity Theory Interactions

MedspaceXR

MedspaceXR was the simulation program chosen for this research project. Students used the simulation to practice radiographic positioning on their own time to supplement a lack of laboratory practice time. The following is the description of the software program by the manufacturer as found in the MedspaceXR instruction manual:

> MedspaceXR™ is a virtual radiography room complete with full patient movement, realistic and fully moveable digital radiography equipment and interactive control panel for exposure settings. As well, students have different viewing options to allow for true immersion and work flow process. Including:

- Interaction with all pieces of equipment via drop down menus or short cut keys
- Interaction with and manipulation of the patient as a whole or through individual part movements
- Altering camera perspectives, including viewing as the radiographer; from the collimator; from the side of the selected Bucky; and the control area for exposure. Selection is via drop down menusor short cut Function keys.
- Extra features which include patient ability to skeletonise.
- Resulting "Virtual" image directly relating to individual patient positioning and exposure selection
- Student image comparison with pre-programmed 'technical standard'
- Student immersion in the 'process' of performing a medical imaging examination (Medspace.VR, 2017, p. 4)

MedspaceXR was chosen to use for this research project for multiple reasons. First and foremost, MedspaceXR allows students to virtually practice positioning radiographic examinations in an open-lab format. The program operates as a "sandbox", meaning it gives no instructional curriculum or criteria to accomplish for the students; students can use the program in the best ways they see fit without being guided or forced to use the program in a predetermined way. This open format and lack of rigid structure is how in-person laboratory practice sessions on campus operate. Secondly, the software licenses are transferable with a one-time purchase; this way the simulation software could be used by different cohorts of students year after year without requiring additional financial investments. Finally, MedspaceXR was chosen because was affordable for the radiography program to purchase.

Participant Characteristics

All 21 students in the 1st year cohort were invited to participate in using the virtual radiography simulation. However, only 13 students actually downloaded and used the software program. All 13 of these students completed the survey. Of those who completed the survey, participants whose average score on the STO criterion represented the 4 highest scores (4.29 – 4.93) and the 4 lowest scores (3.00 – 3.64) were selected for interviews. All students chosen for interviews agreed to participate in interviews.

The survey respondents formed a fairly homogeneous group. Demographic information is displayed in Table 4. The average age of the survey participants was 23; the average age of the whole 1st year radiography student cohort (n=13) was 25.4. All survey participants were female; the whole 1st year radiography student cohort had 20 females and 1 male. Of the survey participants, 12 identified as "White" while 1 identified as "Native American"; in the whole 1st year radiography student cohort 19 identified as "White, 1 as "Native American", and 1 as "Hispanic".

Table 4. Respondent Demographics

Age	20	21	23	24	26	27	Skipped
Frequency	2 (15.4%)	1 (7.7%)	5 (38.5%)	1 (7.7%)	1 (7.7%)	1 (7.7%)	2
Gender	Female	Male					
Frequency	13 (100%)	0 (0%)					
Ethnicity	White	Native American					
Frequency	12 (92.3%)	1 (7.7%)					

Research Question 1 Analysis

The survey instrument of this ESR study sought to investigate research question 1: "What do students report as to their own self-efficacy and positioning skills after using a virtual radiography simulation program?" Students' self-reported positioning skills and self-efficacy scores were collected through the use of a survey instrument. The survey instrument was adapted from the instrument used by Shanahan (2016b). The survey items were scored on a 5-point Likert scale (5-strongly agree, 4-agree, 3-neither agree nor disagree, 2-disagree, 1-strongly disagree). The scores indicated to what degree the students agree or disagree with each statement in relation to using the virtual simulation positioning program. The exceptions were the second section (Rule – Student – Tool), which allowed students to enter the amount of time spent with the software, and the fourth section (Student – Community – Tool), in which students selected one of three options describing their learning preferences. The survey instrument also contained items about participant demographic information such as gender, age, and race. The survey items were designed to explore the intersections of the key tenets of AT. Because of the small number of surveys administered, only descriptive statistics were used for analysis of the survey data.

The survey instrument used for the quantitative phase was administered through Qualtrics, an online survey program. Qualtrics stored the aggregate data from the submitted surveys. Access to the results was password protected, and only the researcher had access. The survey link was distributed to students via email. The students had 1 week to complete the survey. Results from the quantitative survey were used to formulate questions for the individual interviews and centered on common themes identified.

<u>Student – Tool</u>

Student perceptions of using the virtual radiography simulation are displayed in Table 5. Overall 76.9% responded favorably to the survey item "I liked using MedspaceXR" by choosing "Agree" or "Strongly agree". Despite this, about 1/3 of the students each chose a favorable, neutral, or non-favorable response to "MedspaceXR is easy to use" and "Technical problems made using MedspaceXR difficult". It should be noted that the item "Technical problems made using MedspaceXR difficult" is negatively worded compared to the other items; therefore higher student agreement (i.e. higher Likert scale response) with this item meant the student perceived technical problems made using the simulation difficult.

Table 5. Student – Tool Survey Results

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Mean	N
I liked using MedspaceXR	1 (7.7%)	1 (7.7%)	1 (7.7%)	8 (61.5%)	2 (15.4%)	3.69	13
MedspaceXR is easy to use	1 (7.7%)	3 (23.1%)	4 (30.8%)	5 (38.5%)	0 (0.0%)	3.00	13
Technical problems made using MedspaceXR difficult	0 (0.0%)	4 (30.8%)	4 (30.8%)	3 (23.1%)	2 (15.4%)	3.23	13

<u>Rule – Student – Tool</u>

The "Rule – Student – Tool" item on the survey asks students how much time they spent using the simulation. Students were asked to spend at least 1 hour each week using the simulation program. Since using the simulation program was voluntary and was not tied to a grade in a course, there was no way to track the actual time students spent using the simulation program. The results are grouped into categories of average time spent per week and are displayed in Figure 5. Most students self-reported using the simulation program for 30 minutes or less on average per week, while only one student reported using the simulation for more than 60 minutes on average per week.

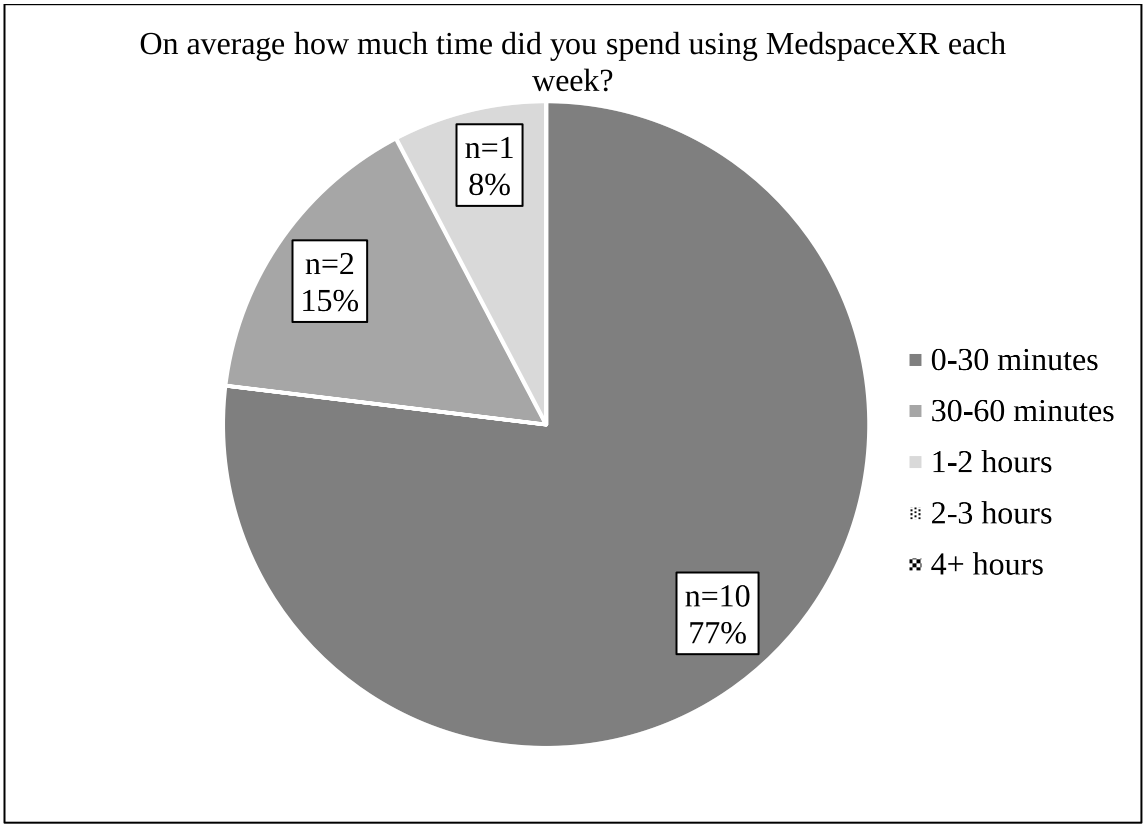

Figure 5. Rule – Student – Tool Results of Use Time

<u>Student – Tool – Outcome</u>

The "Student – Tool – Outcome" category on the survey was divided into 2 subcategories: student competence and student self-efficacy. Both competence and self-efficacy influence a student's preparedness to enter the clinical setting. Student competence relates to a student's ability to perform tasks related to patient interaction, including positioning and patient care, and image acquisition. Student self-efficacy is a student's confidence in his or her own abilities to accomplish a required task. Survey items related to competence asked students to determine to what degree they agree or disagree with statements about how the simulation affected their ability to set up and manipulate radiographic equipment, position the patient, and acquire and evaluate a radiographic image (average score: 3.86). Survey items related to self-efficacy asked students to determine to what degree they agree or disagree with statements about their own confidence, ability to self-evaluate, and opportunity to process thoughts and problem solve (average score: 3.93).

The average scores per subcategory and overall for the STO interaction are listed in Table 6. Overall average responses in the 2 subcategories were favorable. Almost 68% of respondents agreed to some degree with the items in student competence, and almost 73% of respondents agreed to some degree with the items in student self-efficacy.

Table 6. Average Student – Tool – Outcome Response by Subcategory

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Mean	N
Student Competence average	0 (0.0%)	0.76 (5.8%)	3.43 (26.4%)	6.00 (46.2%)	2.81 (21.6%)	3.86	13
Student Self-Efficacy average	0 (0.0%)	0.14 (1.1%)	3.43 (26.4%)	6.57 (50.5%)	2.86 (22.0%)	3.93	13
Overall Student – Tool – Outcome average	0 (0.0%)	0.36 (2.7%)	3.50 (26.9%)	6.29 (48.4%)	2.86 (22.0%)	3.90	13

Student self-reported scores related to competence are displayed in Table 7. Over half of the students either agreed or strongly agreed with the student competence items. The largest agreement scores came from the items “Helped me learn as I was able to repeat activities until I was satisfied with the results” (4.08) and “Had a positive effect on my ability to set up a radiographic examination” (4.08). The lowest agreement score came from the item “Enhanced my image evaluation skills” (3.46). This is understandable as the students were asked to use the simulation program to practice positioning skills and not specifically for the purpose of image evaluation. Also, the simulation program provided no feedback or instruction as to how to properly evaluate a radiographic image, only that the student was able to produce an image based on how they manipulated and aligned the patient, equipment, and technical exposure factors.

Table 7. Student - Tool - Outcome: Student Competence Survey Results

Using MedspaceXR...	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Mean	N
Enhanced my routine procedure for setting up radiographic examinations	0 (0.0%)	0 (0.0%)	4 (30.8%)	7 (53.8%)	2 (15.4%)	3.85	13
Allowed me to quickly see images and understand if changes needed to be made	0 (0.0%)	0 (0.0%)	4 (30.8%)	5 (38.5%)	4 (30.8%)	4.00	13
Enhanced my image evaluation skills	0 (0.0%)	2 (15.4%)	5 (38.5%)	4 (30.8%)	2 (15.4%)	3.46	13
Helped me become more fluent or systematic in a radiographic examination e.g. not repeating steps	0 (0.0%)	0 (0.0%)	4 (30.8%)	6 (46.2%)	3 (23.1%)	3.92	13
Helped me learn as I was able to repeat activities until I was satisfied with the results	0 (0.0%)	1 (7.7%)	2 (15.4%)	5 (38.5%)	5 (38.5%)	4.08	13
Had a positive effect on my ability to set up a radiographic examination	0 (0.0%)	0 (0.0%)	1 (7.7%)	10 (76.9%)	2 (15.4%)	4.08	13
Had a positive effect on my ability to evaluate radiographic images	0 (0.0%)	1 (7.7%)	5 (38.5%)	5 (38.5%)	2 (15.4%)	3.62	13

Student self-reported scores related to self-efficacy are displayed in Table 8. With the exception of 1 item, over half of the respondents agreed or strongly agreed with the student self-efficacy items. The largest agreement scores came from “Encouraged me to think more about radiographic procedures” (4.08) and “Encouraged me to think more about evaluating radiographic images” (4.08). The lowest score came from the item “Had a positive effect on my ability to self-evaluate when I evaluate radiographic images” (3.77). Again, this is understandable as student image evaluation was not part of how students were asked to use the simulation program. It is interesting to note that the highest and lowest scores in this subcategory were related to image evaluation. While the ability to self-evaluate images was scored low, the simulation’s effect of encouraging students to think more about evaluating radiographic images was scored relatively high in comparison.

Table 8. Student - Tool - Outcome: Student Self-Efficacy Survey Results

Using MedspaceXR...	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Mean	N
Had a positive effect on my confidence level in setting up radiographic examinations	0 (0.0%)	1 (7.7%)	2 (15.4%)	8 (61.5%)	2 (15.4%)	3.85	13
Had a positive effect on my confidence level in evaluating radiographic images	0 (0.0%)	0 (0.0%)	3 (23.1%)	9 (69.2%)	1 (7.7%)	3.85	13
Had a positive effect on my ability to self-evaluate when I set up radiographic examinations	0 (0.0%)	0 (0.0%)	3 (23.1%)	8 (61.5%)	2 (15.4%)	3.92	13
Had a positive effect on my ability to self-evaluate when I evaluate radiographic images	0 (0.0%)	0 (0.0%)	5 (38.5%)	6 (46.2%)	2 (15.4%)	3.77	13
Encouraged me to think more about radiographic procedures	0 (0.0%)	0 (0.0%)	4 (30.8%)	4 (30.8%)	5 (38.5%)	4.08	13
Encouraged me to think more about evaluating radiographic images	0 (0.0%)	0 (0.0%)	3 (23.1%)	6 (46.2%)	4 (30.8%)	4.08	13
Encouraged me to solve problems	0 (0.0%)	0 (0.0%)	4 (30.8%)	5 (38.5%)	4 (30.8%)	4.00	13

Student – Community – Tool

Community in Activity Theory describes how the user interacts with the tool and with others. Students in this study were not given any instructions as to how they used the tool alone or with others. Though the simulation can only be operated by one user at a time, students in other studies were given the option to use the virtual simulation alone or to collaborate with others to simulate a radiographic exam (Shanahan, 2016a; Shanahan, 2016b). There was no expectation as to whether or not they would use it by themselves or with others in this study. The items on the survey instrument related to community asked students if they learned best using the simulation program by themselves, with other, or both. The results are displayed in Figure 6.

Over half of the students responded that they prefer using the simulation program as an individual activity. Only 1 student preferred using the simulation as a shared activity (i.e. with 1 or 2 other students).

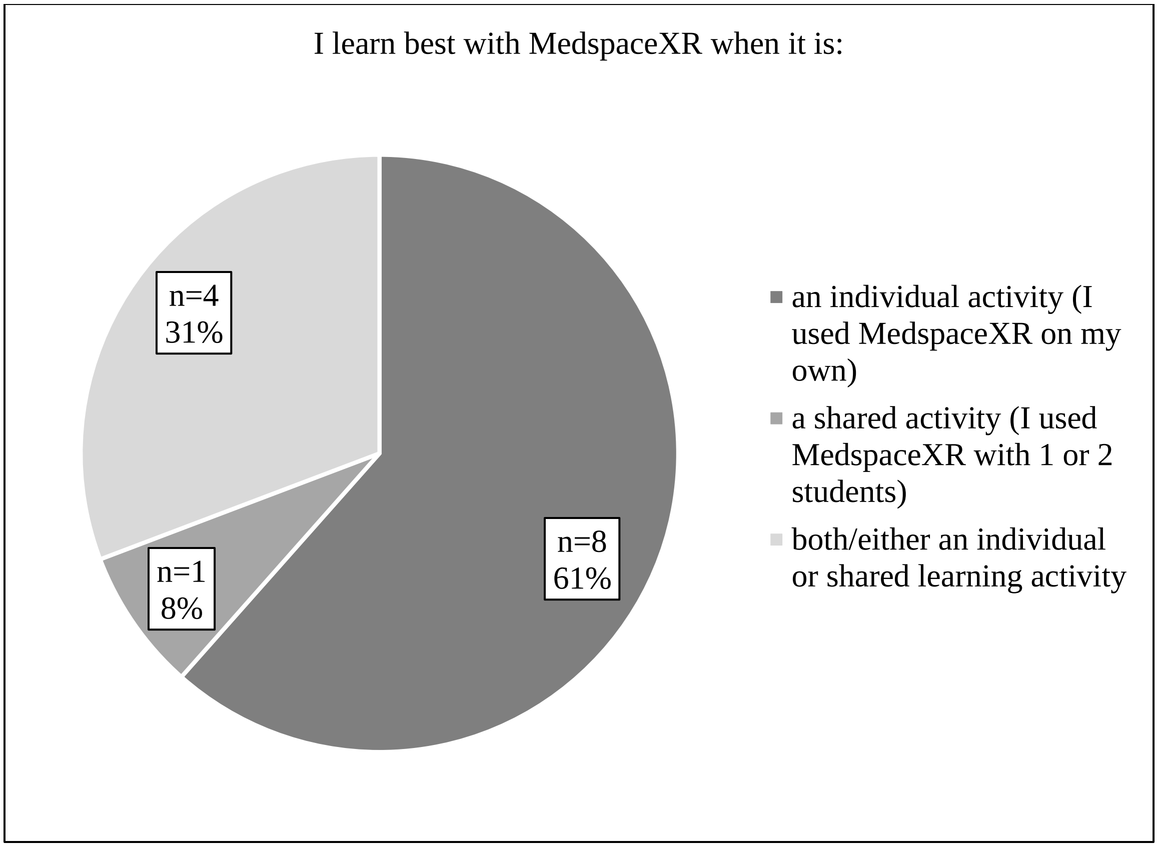

Figure 6. Student – Community – Tool Preference

<u>Division of Labor – Student – Tool</u>

In Activity Theory, division of labor refers to who or what is giving the instruction as to what the purpose of the tool is or how the tool can be used. In this study, division of labor referred to the ability of the simulation program to be a valuable, self-regulated tool and how students relied on each other to help them use the tool. Students were given a brief tutorial in class on how to use the simulation program. The only other instruction given to students as to how to use the simulation program was that students were to use the program however they saw beneficial. The students were not given any set of specific objectives, assignments, or tasks to accomplish. The purpose of giving the student the simulation program was so they could use it in the best way they found most productive and to give them a virtual space to practice what they were learning in class and labs.

The results of the Division of Labor – Student – Tool survey items are displayed in Table 9. Though the simulation provided no specific instructions or objectives on how to position the patient or the equipment to perform a radiographic exam, almost all the students (84.6%) agreed to some degree with the statement “MedspaceXR was designed to help guide me through positioning activities”. Just over half the students (61.5%) agreed to some degree that the simulation’s tutorial and help guide was valuable. Approximately 1/3 of the students disagreed to some degree that they relied on other students to help them learn using the simulation program; however, only approximately 1/3 of the students agreed with the same statement. This is in contrast to the Student – Community – Tool statement in which almost 62% of students preferred using the simulation as an individual activity.

Table 9. Division of Labor - Student – Tool Survey Results

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Mean	N
MedspaceXR was designed to help guide me through positioning activities	0 (0.0%)	0 (0.0%)	2 (15.4%)	7 (53.8%)	4 (30.8%)	4.15	13
The MedspaceXR reference guide was a valuable tool in helping me use the VR program	1 (7.7%)	1 (7.7%)	3 (23.1%)	7 (53.8%)	1 (7.7%)	3.46	13
I relied on other students to help me learn using MedspaceXR	2 (15.4%)	2 (15.4%)	5 (38.5%)	4 (30.8%)	0 (0.0%)	2.85	13

Summary of Survey Data for Research Question 1

Research question 1 focused on students' self-reported self-efficacy and positioning skills after using MedspaceXR. Data was collected using a survey instrument built on AT framework and adapted from the study conducted by Shanahan (2016b). Overall the majority of students liked using MedspaceXR, and they thought the program improved their self-efficacy and positioning skills. Students also preferred to use the simulation alone and found the simulation was able to guide students through positioning activities.

They key area for exploring self-efficacy and positioning skills is found in the AT category of "Student – Tool – Outcome". Students particularly agreed with statements of self-efficacy on the subjects of thinking more about radiographic procedures, evaluating radiographic images, and problem solving. Students also agreed strongly with statements about positioning skills on the subjects of exam setup, learning through repeated practice, and making adjustments to correct problems.

The average score of each response to Likert-scale items was neutral or favorable, with the exception of one. One scale item was a negatively worded question, and when the scale was reversed the response would have been an average of less-favorable than neutral. Students on average slightly agreed that technical problems made using the simulation program difficult.

Research Question 2 Analysis

The qualitative portion of this ESR study sought to investigate research question 2: "What are students' perceptions of their own self-efficacy and positioning skills after using the virtual radiography simulation program?" Students' perceptions of their positioning skills and self-efficacy were collected through interviews.

The interview questions were developed to explain the items in the survey and aligned to explore the intersections of the key tenets of AT. The questions were determined before any interviews were conducted. All interviewees were asked all the predetermined questions; however, additional follow-up questions were asked as needed to help clarify responses, explore salient comments, and elicit more discussion. As noted, participants whose average score on the STO criterion of the survey instrument that represented the 4 highest scores and the 4 lowest scores were selected for interviews. All students chosen for interviews agreed to participate in interviews. SignUpGenius (www.signupgenius.com) was used to schedule interview times; sign-up times were established and sent an invitation via email to the interview participants to sign up for an available time.

Originally the interviews were planned to be conducted in person, but due to the COVID-19 circumstances in Spring 2020, interviews were conducted and recorded via Zoom. Memoing was used during the interviews to record impressions and thoughts about students' responses. The interviews were transcribed using Temi (https://www.temi.com/) and then checked and corrected for accuracy. After all the interviews were conducted and transcribed, the data documents (i.e. transcriptions and memos) were then imported into NVivo to help analyze the data for codes and themes as well as to keep track of coding categories across various sources of qualitative data.

Saturation was reached by the 4th overall interview. The interview data was analyzed in alphabetical order based on the pseudonym assigned to each interviewee.

Coincidently, the first 4 interviews analyzed happed to be the students with the 4 highest STO scores from the survey; this order of interviews was unintentional. The order within the first 4 interviews and the second 4 interviews was random and did not demonstrate an exact replica of high to low STO scores. Still, even though the first 4 interviews were associated with the 4 high STO scorers from the survey, no major themes emerged in the remaining 4 interviews. However unique examples and experiences of the major themes were shared in the last 4 interviews.

Interviewee Characteristics

Survey respondents whose average score on the STO criterion represented the 4 highest scores and the 4 lowest scores were selected for interviews. Figure 7 shows the students' average response to the Student – Tool – Outcome category from the survey. Participants were each given a pseudonym for the purpose of anonymity. Student IDs 5, 13, 10, and 9 were chosen as the students with the 4 lowest average scores, while student IDs 1, 2, 12, and 11 were chosen as the students with the 4 highest average scores. All 8 of the students selected for interviews agreed to participate. Student characteristics and assigned student ID are listed in Table 10.

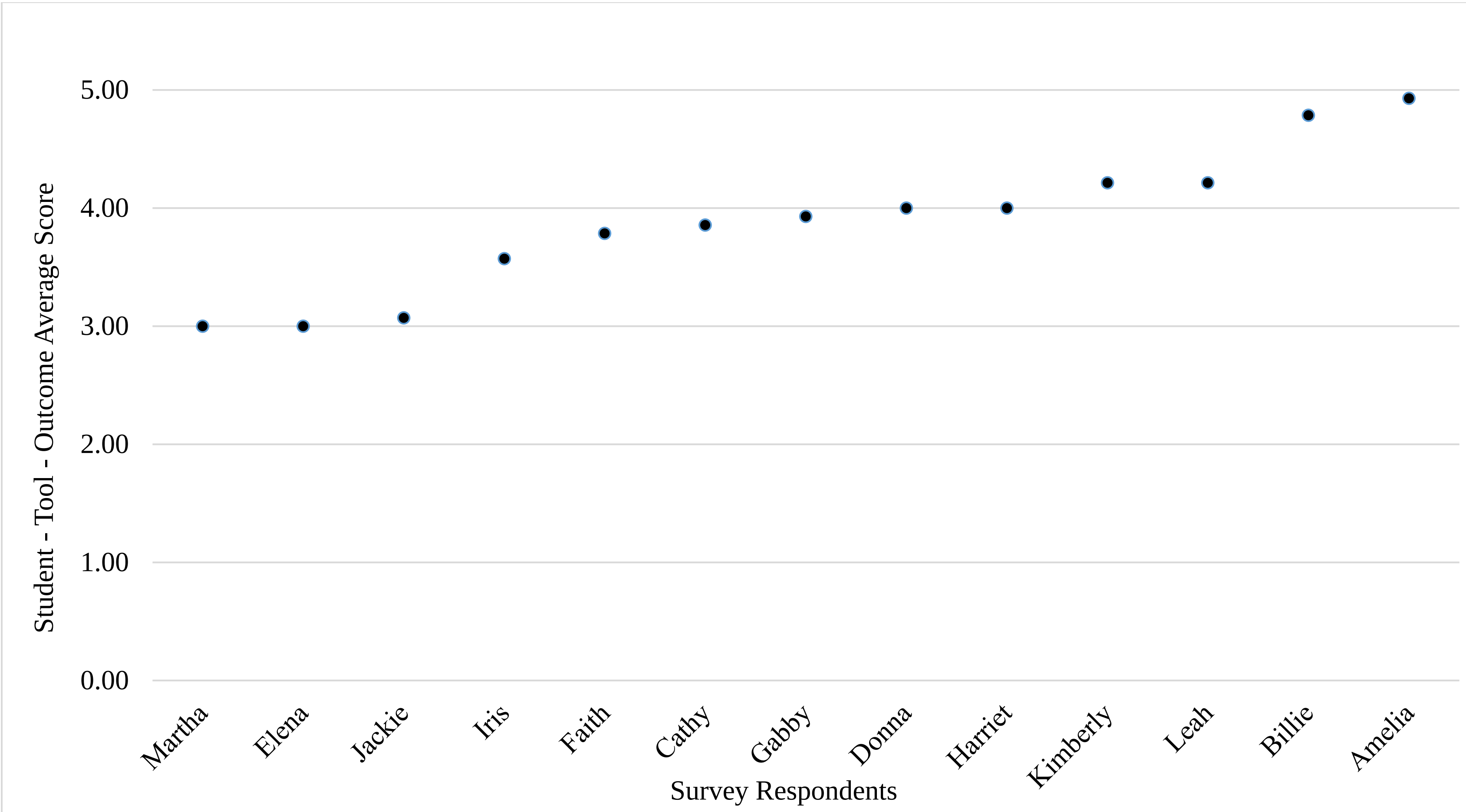

Figure 7. Scatter Plot of Student – Tool – Outcome Average Score by ID

Table 10. Interview Participant Characteristics

Pseudonym	Average Sim Use Time	Ave STO score	Age	Gender	Prior Degree	Prior Radiology Experience
Martha	0-30 min	3.00	27	Female	Bachelor	Radiology transporter
Elena	0-30 min	3.00	23	Female	None	Limited x-ray program
Jackie	0-30 min	3.07	23	Female	None	None
Iris	0-30 min	3.64	23	Female	None	None
Kimberly	30-60 min	4.29	24	Female	None	None
Leah	1-2 hrs	4.36	26	Female	None	None
Billie	0-30 min	4.79	20	Female	None	None
Amelia	30-60 min	4.93	23	Female	None	None

Coding

Codes were identified in the interview and memoing data using First Cycle and Second Cycle Coding (Saldaña, 2016). Descriptive coding was used to assign a word or phrase to each sentence or paragraph of the qualitative data. The word or phrase summarized the overall topic of each passage of qualitative data. Each interview and corresponding memo was analyzed for codes before moving to the next interview. New codes emerged frequently when initially sorting through the data. During the coding process, codes began to be repeated in the data, and eventually no new codes were identified by the last interview analysis.

After the First Cycle Coding of descriptive coding, the interview and memo data was analyzed again during Second Cycle coding using focused coding. Focused coding uses the most frequent or significant codes from First Cycle Coding to develop the most pertinent categories. The codes identified in focused coding were labeled as the major themes of the qualitative data. All of the interview and memo data fit into at least one of the major themes. The themes identified from the coding process are listed in Table 11.

Table 11. Coding Themes, Subthemes, Definitions, and Examples

Theme	Subthemes	Definition	Example
Student Self-Efficacy		Any reference to a student's confidence in their own abilities and confidence to handle various situations	Kimberly: And it definitely makes me feel more confident that I remember all of, all of the positions for whenever we test or like get ready to do competencies and stuff.
Student Positioning Skills		Any reference to a student's psychomotor skills to perform radiographic exams, equipment manipulation, image acquisition, and patient interaction skills	Amelia: I feel like it helped, um, it did help me, like with the positioning or knowing where to put the tube head or like angling and stuff like that. So skill-wise, it did help because I had practiced them previously, even though it wasn't on a real patient, it's still like what's in my mind and I was able to gain better skills that way.

Using the Simulation	Ease of use
	Sim as a self-regulated tool
	Sim use time
	Technical issues
	    Computer issues
	    Metric vs English units
	    Moving the sim patient
	    Positioning difficulties
	    User error issues
	Trial and error
	Using sim outside class/lab
	Using sim alone
	Using sim with others
		How students used the sim program, what ways the students used the sim, and what barriers diminished their experience	Jackie: But I kind of felt like it was hard for me to use. Like in a little bit of a way, like sometimes like... I wish that you could like click the patient's arm and then just like move the patient's arm without having to like, do the other buttons.

Simulation Characteristics	Exposure technique Ideal radiographic image Practice Lack of sim patient variation	Positive and negative characteristics of the sim identified by students	Leah: We have pictures of what it's supposed to look like, like the picture. So you can get it all set up and then take an image how you think it should look and then you can compare and go back and

	Visualization “I liked it”		fix it until you get to like their idea of perfect. And it prepares you better for clinicals.
Academics	Lab tests Positioning class Teacher instruction	How students associated using the sim to didactic content, courses, and labs	Elena: I relied a lot on the knowledge that [the course instructor] had taught. Um, I wouldn't have been able to manipulate the program and figure out how to get the positions without having been taught that in school… Um, but yeah, I think that the classroom instruction, or just having someone show me, um, in real life was kind of a foundation to being able to use that.
Translation to the Real World	Student clinical performance Student preparation Background/starting point	How confidence and skills students gained from using the simulation translated to the clinical setting	Billie: But since like being able to use like the tools given to us in class, as well as the simulation and you know, I feel confident like telling the tech kind of like I've got this, like I know what I'm doing. And like I can do it correctly on the first try because I've had a bit of a background to rely on.

Primary Themes

The major themes identified in the interviews were “Student Self-Efficacy”, “Student Positioning Skills”, “Using the Simulation”, “Simulation Characteristics”, “Academics”, and “Translation to the Real World”. The first three themes relate directly to the research questions and questions developed for the interview. The last three themes developed as feedback to students’ experiences using the simulation program.

Student Self-Efficacy

In the “Student – Tool – Outcome” portion of the interview, students were asked specifically “How do you feel the simulation program affected your self-confidence?” However, the topic of self-efficacy was found throughout each interview and among all the interviews. When meaning “self-efficacy”, students primarily used terms like “confidence” and “self-confidence”. Interestingly, comments about self-efficacy often started with emotional phrases such as “I feel”. Students’ comments about self-efficacy mostly related to confidence in their own abilities and confidence to handle various situations.

Student Positioning Skills

In the “Student – Tool – Outcome” portion of the interview, students were asked specifically “How do you feel the simulation program affected your clinical skills?” However, like self-efficacy, the topic of positioning skills was found throughout each interview question and among all the interviews. When referring to “positioning skills”, students would often use terms like “clinical skills” or just “skills”. However, unlike comments about self-efficacy which contained emotional phrases, comments related to skills often started with knowledge phrases such as “I think”. Students’ comments about positioning skills also incorporated other clinical skills such as equipment manipulation, image acquisition, and patient interaction skills.

Using the Simulation

Comments about how students used the simulation program were found throughout each interview. These comments also described in what ways students used the program and what barriers diminished their experience. Subthemes of "using the simulation" included: ease of use, simulation as a self-regulated tool, simulation use time, technical issues, trial and error, using the simulation outside of class or lab, using the simulation alone, and using the simulation with others. The "technical issues" subtheme had a number of subthemes in itself, such as computer issues, metric vs English units, moving the simulated patient, positioning difficulties, and user error issues.

Simulation Characteristics

The "simulation characteristics" theme described characteristics of the simulation specifically identified by the students. Mostly these characteristics where what the students found desirable or beneficial when using the simulation program. Subthemes identified were related to exposure technique, the ideal radiographic image, practice, lack of simulated patient variations, and visualization. One additional subtheme included an affectation of some form of "I liked it", referring to their use of the simulation program.

Academics

The "academics" theme related to how students would use or associate using the simulation program to didactic content or course grades. It is interesting to note that even though use of the simulation program was not required and not tied in any way to an academic grade, students still linked using the simulation to performance in academic assessments and course material. Subthemes identified in academics included lab tests (i.e. student skill assessments with a simulated patient in a laboratory setting), positioning class (i.e. the didactic class in which students learn specific positioning information and requirement), and teacher instruction.

Translation to the Real World

The "translation to the real world" theme combined ways in which students identified how confidence and skills they gained while using the simulation program translated to real patients in a clinical setting. Subthemes include how student performance was impacted at clinicals, student preparation, and how the stimulation gave students some background or a starting point to build knowledge and skills.

Student – Tool

In the Student – Tool section of the interview, students were asked about their experience using the tool and how the interacted with the tool. Questions revolved around the topics of how well students liked using the program, ease of use, technical problems, and benefits and limitations of the program. While all the primary themes were identified in the responses, the majority of responses involved the themes *using the simulation* and s*imulation characteristics* (see Figure 8).

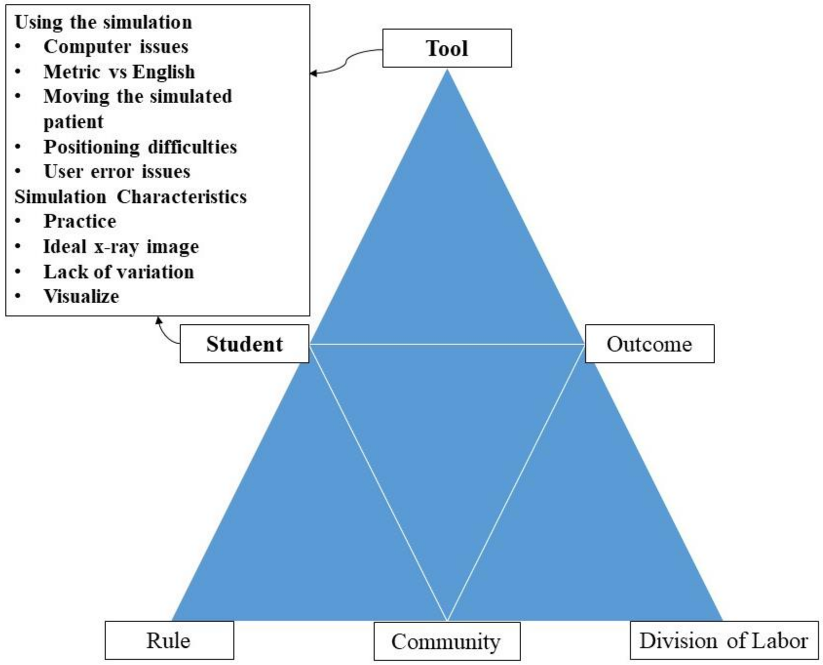

Figure 8. Student – Tool Primary Themes

Using the Simulation

Initially most of the students found the program difficult to use. None of the students had any previous experience using virtual simulations or 1st person video games, so most students found maneuvering the avatar in the virtual environment was challenging. Figure 9 shows a screenshot of the simulation's virtual radiography room and patient from a 1st person view. It was also challenging for them to manipulate the avatar to see what the student wanted to see in the virtual environment.

Jackie: Overall it was, it was kind of hard to use a little bit, um, like moving the bodies or the Bucky in the table. Like I found it really difficult to use it, um, and always having to toggle between views to try and... Just well learn and be able to see what I was actually doing when I was doing those things. So that was kind of difficult for me to really have that, you know, when you're in an exam and you're looking down and seeing what you see, like, that was difficult for me to be able to see, um, when I'm trying to position them like flat or move them around and then try to hurry and switch up top and it just speak completely off. So that was kind of difficult for me.

Kimberly: Um, like it definitely took, took some work to figure it out. Cause I'm, I don't do a lot of like online gaming and things like that. So like the keys to make him move and stuff like you, you know, have it, cause you do that stuff, but I'm like what? Like that doesn't make any sense to me. So like once I figured that out, I think that it was, it was fairly easy to use.

Figure 9. 1st Person Avatar View in MedspaceXR

However, most students reported that the simulation became easier to use the more they used it. Time and increased familiarity with both the virtual environment and the controls helped improve the ease of use.

An unexpected subtheme of Using the Simulation emerged in the form of *computer issues*. It was discovered that the computer simulation software was not compatible with Mac computers. One student had to download the simulation program on a campus lab computer and therefore wasn’t able to use the simulation at home. Another students found the simulation program caused mechanical problems with her laptop.

Leah:	Um, downloading it was hard and while I'm running it, it kind of burns up my laptop pretty good.
Interviewer:	Okay, what do you mean by "burns it up"?
Leah:	I don't know, like it just overheats really fast the whole time I'm using it. And I have to keep it like plugged in, too, cause it drains the battery.

A final computer issue noted was one student’s lack of a mouse for their laptop. The student found using the track pad very difficult to interact with the simulation.

Another unexpected subtheme of Using the Simulation came in the form of *Metric vs English* units of measurement. Radiographers use standard source-to-image receptor distances (SID) for various radiographic exams. The standard SIDs used in the United States are measured in English units of distance as 40” and 72”. Students learn which exams are associated with each SID. The difficulty in using the simulation program in regards to SID arose because the simulation program was developed in Australia, which uses the metric system to measure distance (see Figure 10). Using a different measurement system was confusing for students who are already novices and trying to learn so many other aspects of radiographic exams.

Jackie:	Um, another limitation that I found for me and I'm just because this is, I believe it's Aus... Is an Australian company or that made it, yeah? Is that it's not in our units that we use. And so I always be like, "Hey Siri, how many centimeters are in 72 inches?" So having an actual ruler.

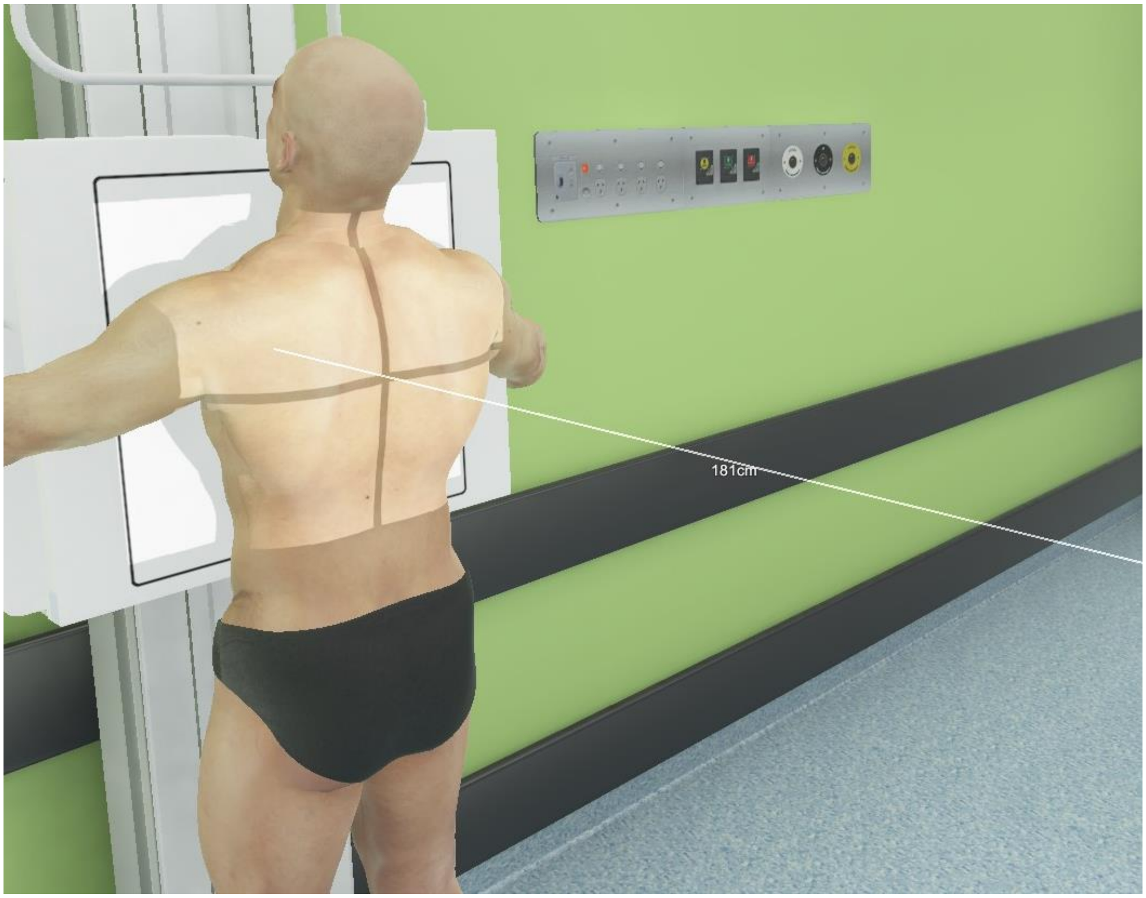

Figure 10. Distance measurement in Metric Units.

Though there were difficulties using the simulation program, some students enjoyed the versatility and variability of the simulation program, especially in *moving the simulated patient* and *positioning difficulties*. Since the simulation was not designed in a progression model (i.e. completing a series of tasks or objectives before being allowed to move onto the next exam) and instead was more of an open “sandbox” format (i.e. the entire program was open to students from the beginning), students reported more difficulties when first starting to use the program.

Amelia: So I liked being able to see a patient in front of me and like practice positioning. I feel like I could go through all the steps and just kind of get in the groove of things.

Kimberly: I think that I liked that you could position him and take X-ray and see kind of how it would look after you took it. Um, and I liked how you could position different ways.

The more students used the program, the more comfortable they became with the program and using it to practice exams.

Amelia: Well, anyone like the big limitation is just not knowing how to use it. Um, and like maybe that could be cured with a lot more practice.

This development of comfort also follows how students gain comfort and familiarity in a real-life clinical setting.

There were a number of comments by the students which were coded as *user error issues*. Some comments were about the difficulties of the simulation program, for instance students not knowing how to access a menu or manipulate the virtual equipment. This was especially true when compared to real-life laboratory environments where finding and physically manipulating equipment is much easier.

Amelia: I think like just not having like a little menu box right there, or like maybe some arrows or a little indications on click here to walk over here. I just kind of had to click around if that makes sense.

Billie: I think the biggest complication I had with it though was just like the technical side of it of figuring out how to move the person around and stuff. Not actually like figuring out how, like I knew what position I was doing and like how I should be positioning the person, but sometimes it was like, "turn left, turn left!"

Most of the comments coded as user error issues center on students inability to use the simulation program due to their own lack of experience rather than a problem with the simulation itself.

Amelia: Um, I just remember like looking through the eyes of the radiographer and just seeing a room and a patient standing at the board, or sometimes there was no patient and I had a hard time figuring out, okay, how do I get the patient onto the table? Or how

> do I walk over to the console? Like, how do I take the X-ray? So like, I spent more time trying to figure out the technical side rather than actually practicing with that patient.

Overall the students' responses identified by the theme *using the simulation* were mixed and varied. Most students found the program difficult to use at first and easier to use the more practice they had with it. There were unexpected errors in computer issues and units of distance measurement, but most barriers to using the simulation program were from students' own lack of skills in using the simulation program and not barriers in the program itself.

Simulation Characteristics

Respondents identified four main characteristics about the simulation when asked about how they interacted with the virtual simulation program: practice, seeing the ideal radiograph, the lack of variation in the simulated patient, and the ability to visualize an exam. As noted, the ability of the students to use the simulation program impacted their perceptions of its usefulness. However, as students became more comfortable using the simulation and manipulating various factors virtually, most commented on the ability to *practice* using the simulations and the benefits of repetition and unstructured practice.

> Elena: I think, um, it wasn't super user friendly, but once I got the hang of it, um, I think it was helpful to be able to just kinda like mess around in an X-ray room. Um, cause we can't do that other than in our labs or at clinicals. Um, just the ability to do extra practice, um, when you're away from the equipment. I think, cause I'm a person who needs a lot of repetition to learn things and um, just having time at clinicals or at labs sometimes there's things that I need to work through kind of on my own. And so being able to do that through like a virtual thing is helpful.

An unexpected theme that emerged was the students' ability to see what the *ideal X-ray image* would look like. MedspaceXR allows users to not only virtually position the patient and radiographic equipment but to also virtually exposure the resultant exam and see what the alignment of the equipment and patient and technical factors would produce on a radiograph (see Figure 11). After this virtual exposure, MedspaceXR also allows the user to see what it has preprogramed as the ideal equipment and patient positioning, technical factors, and resultant radiographic image (see Figure 12). This feature gives the user a standard or goal for the production of a given exam to which they can compare their own performance.

In the traditional laboratory practice setting, students practice physically positioning each other for various radiographic exams; however, the students do not expose each other to X-rays and produce a radiographic image. Exposing someone to radiation unnecessarily or without a medical provider's order is unethical and illegal. Therefore in educational laboratory settings students only practice positioning on each other and not actual image exposure. So, when students were asked to use the simulation, it was not anticipated that students would use the image exposure feature to practice radiographic positioning. This aspect of virtual radiographic image exposure was not part of the original investigation as to how students interacted with the simulation or how the simulation impacted their positioning skills or self-efficacy. Still, a number of students commented on this feature in how they interacted with the simulation.

Leah: Um, they have like, how'd they put it, we have pictures of what it's supposed to look like, like the picture. So you can get it all set up and then take an image how you think it should look and then you can compare and go back and fix it until you get to like their idea of perfect. And it prepares you better for clinicals.

Iris: I also, um, like through the being able to, when you take the exposure, you can see it, um, and being able to correlate, like I can start seeing that sometimes I usually creep down on my X-rays. So it also helps with like knowing where to center or, um, you know, maybe I don't see it exactly midline being able to go back and fix that and just having that repetition so that I wouldn't be doing that on a real patient.

Figure 11. Position, Image, and Exposure Technique Created by User

Figure 12. Ideal Position, Image and Exposure Technique Created by MedspaceXR

The *lack of variation in the simulated patient* was identified in numerous comments. The simulated patient was a white male of standard build (i.e. height, weight, and size) (see Figure 13). There were no controls to manipulate the characteristics of the patient such as age, gender, or lack of mobility as is common in geriatric, bariatric, or trauma patients. The simulated patient was compliant with all directions of movement in positioning for the radiographic exam. This was identified as a barrier to translating the simulation experience to real life.

Kimberly: The one thing that I think that this might be a barrier, so it might actually go back to the last question, but like I wished that there was more like more kind of characters to choose from. Cause we only have this one guy and he has the same build. And like you can't really, like, I wish that there was maybe a lady that you could kind of position her and see how things went. Maybe a little bit of a thicker, chunky patient. And like then you could kind of position them and see how things would look on them because everyone is built so differently.

Billie: So in the simulation, they kind of give you like the ideal patient, you know, you get to move them, they stand still their body type. I think you could just a little bit, but like, obviously everybody's different. So like you can get used to what's on the simulation and then in a clinical setting you'll have somebody that can't stand up or not cooperative. And so it's just like the simulation is kind of the ideal situation. Whereas clinicals are just about anything but.

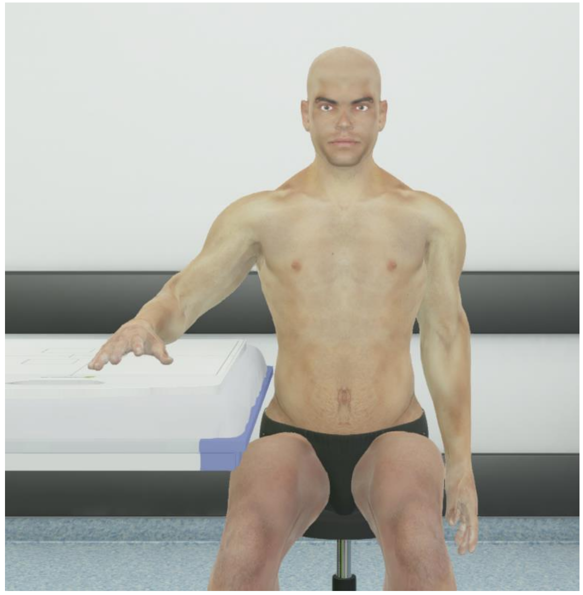

Figure 13. Example of Standardized Patient Available in the Simulation.

The last subtheme of how students interacted with the simulation came in the students' ability to *visualize* the exam instead of just imagine or mentally construct an exam scenario (see Figure 14). This theme is different from being able to see the ideal X-ray image (i.e. the radiograph produced from exposing the patient to X-rays) as it focused on the ability to actually see an example of the exam, the patient positioning, and the equipment setup. The ability to see the X-ray exam especially helped learners.

Billie: So I have a photographic memory, so if I can kind of see, have something to go back on of like, this is how it looked, like that really helps me, um, just being able to see what the X-ray should look like. Cause sometimes we see so many and sometimes like there's some X-rays [exams] we don't see as often. And so being able to like use the simulation to be like, here's an X-ray [exam], like I never do. Like, let's give it a try in the simulation and see what the X-ray should look like.

Amelia: Well, like I said, I think it's very good because as a junior, you are still like struggling to know what's PA what's AP and what's lateral and stuff like that. And so I feel like the software program is really good for seeing it in person and getting to know like what those different positions are and it kind of helps you break it down into steps. And so I feel like as a junior, it is good because you're not familiar with those processes.

Figure 14. Visualizing an Abdomen Exam

The second most coded responses to how students interacted with the simulation program were group as *simulation characteristics*. As expected, students found value in being able to *practice* radiographic exams and *visualize* aspects of performing a radiographic exam such as positioning a simulated patient and virtually manipulating X-ray equipment. Unexpectedly, students commented on the ability to see the *ideal X-ray image* and the *lack of variation in the simulated patient*. These were unexpected responses because students do not have these as options in real-life laboratory practice.

<u>Rule – Student – Tool</u>

The next portion of the interview asked students about how they used the tool in relation to the rule they were given (i.e. the amount of time students spent using the tool). As noted, students were asked to spend at least 1 hour each week using the simulation program. Questions in this section asked students how long they spent using the simulation each week and how they felt the amount of time the spent using the simulation affected their self-efficacy and positioning skills. Given the nature of these questions, it is expected that the common themes identified were *student self-efficacy* and *student positioning skills* (see Figure 15).

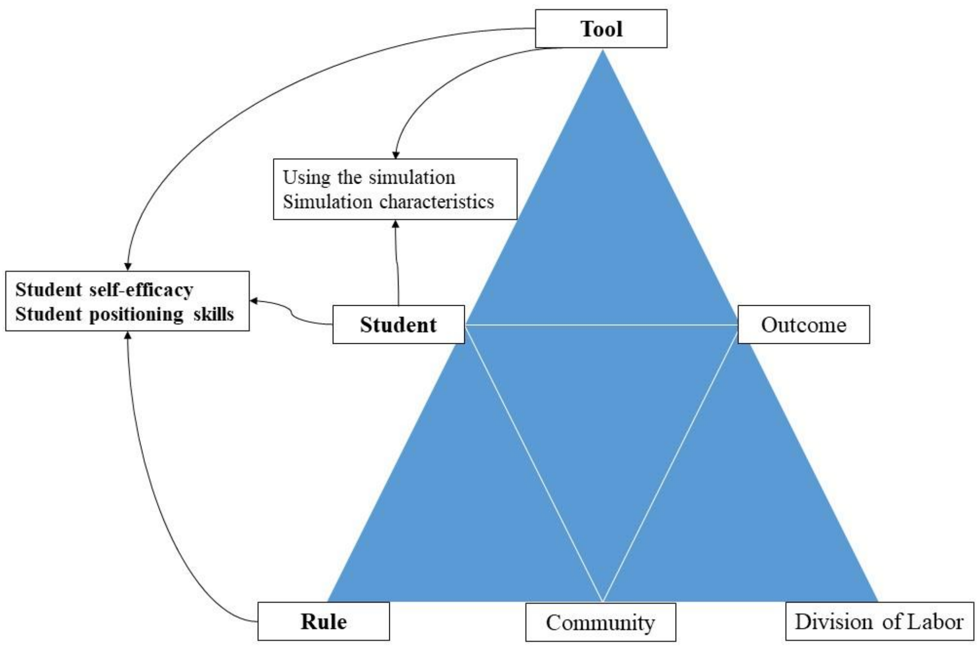

Figure 15. Rule – Student – Tool Primary Themes

In response to how much time students spent using the simulation program, there was a stark difference between the two groups: students with high scores on the STO section of the survey, and students with low scores. Students with high scores reported they spent at least 1 hour each week using the simulation. Three of the four students reported using the simulation 1.5 to 2 hours per week. In contrast, the low scoring students reported using the simulation program for 1 hour each week at most. Two of these students reported using the simulation for only 15-20 minutes per week.

Student Self-Efficacy

Though students were asked to share their thoughts about "self-efficacy", students used the term "self-confidence" in their responses. The students interviewed used the terms "self-efficacy" and "self-confidence" interchangeably. All students commented that they felt using the virtual simulation positively affected their self-efficacy; however, to what degree their self-efficacy was affected varied with the amount of time they used the simulation. Students who used the simulation for more time on average each week noted their self-efficacy increased.

Amelia: It did make me a little bit more confident and more I used it.

Martha: I think if I would have spent more time, it would have boosted my confidence more.

Elena: So it helped me have confidence there that if I walked into a different employment situation, that I would kind of be able to figure out, um, the setup as far as actual positioning, um, being able to get extra practice helps with confidence. Some, um, not a whole lot just because I didn't, I wasn't able to put in more than a couple hours here and there every week, but I think if I would have been able to put more time in, um, the time, the easier it got that would have helped more with confidence. Cause I did see that help. It just wasn't an overwhelming amount for me.

Some students noted that frustrations with not being familiar with the simulation program affected to what degree their self-efficacy increased. These struggles using the simulation caused them to spend more time using the simulation, but less time actually practicing radiographic exams, leading to a negative impression of the simulation program. Their ability to use the simulation program, or rather lack thereof, negatively impacted the simulation program's ability to increase self-efficacy.

Leah: Hmm. I guess you do get improvements, so that's better, but you also get frustrated that sometimes no matter what you do, it's still not like equaling out to the image, like should look like so that I couldn't figure out how to correct on my own, without a tech, I should say, um, those kind of did improve it.

Jackie: Um, well like, like I knew what I was supposed to be doing because it was helping me see it, but just the fact that I couldn't like figure it out, that didn't really affect my self-conf... Like it helped me be a little bit more confident in knowing like, I know what I'm supposed to do next, but I could just never do it, if that makes sense.

Overall students said using the simulation program positively affected their self-efficacy. There was also a positive convergence between simulation use time and perceived increase in self-efficacy. Though some students got frustrated with their inability to make the simulation program do what they wanted, because of a lack of familiarity in using the simulation, even these students still noted an increase in self-efficacy after using the virtual simulation.

Student Positioning Skills

Some students agreed that the amount of time they spent using the simulation program positively affected their positioning skills. They also noted an association in the amount of time they spent with the increase in positioning skills, meaning the more time the spent, the more they felt their positioning skills increased. Interestingly, students who reported greater increases in positioning skills were those who scored the highest in the STO section of the survey and were chosen as the four highest scores for the interview process.

Billie: I think it definitely helped, probably would have helped more if I had used it more, like obviously the more that you use it, the more, uh, things you'll have to look back on and kind of remember like, “Oh, this is how you positioned for that”. Instead of having to like grab the textbook, it's just kind of in your mind instead of something you have to remind yourself of.

Amelia: I think that the more I practice on the simulation program, it did affect my clinical skills in a positive way.

Leah: They improved it, cause I had a better idea of what I was doing before the patient was there. So it wasn't like blindly trying to figure it out or, not blindly, but just struggling I guess.

Unlike self-efficacy, not all students agreed that the amount of time they spent using the simulation positively affected their positioning skills. Some students felt the amount of time they spent using the simulation did not affect their positioning skills. Others shared that no amount of time would have translated to an increase in positioning skills.

Elena: I feel like you had to already know the positioning on how to do everything. So there kind of had to be a base level there to figure out at least from what I gained from trying to do it. Um, I kind of had to have already been taught a little bit, but I don't think that the program itself like taught me anything. It just gave me an opportunity to reiterate my own brain what I had been taught in an actual lab or at clinicals. I don't know if that's a good answer, but that's what I have.

Martha: I don't know if it would have boosted my clinical skills as much. I think it was definitely more of the confident boost and like the knowing, but for me, like I need the hands like on for my skills. I feel like to improve.

Still, none of the students reported a negative outcome in relation to time spent using the simulation and their positioning skills. It was interesting how the four students with high STO survey scores felt their time using the simulation program positively affected their positioning skills, while the four students with low scores felt their positioning skills were not affected by the amount of time they spent using the simulation program.

While all students reported an increase in self-efficacy with more time they spent using the virtual simulation, the same is not true for use time’s association with positioning skills. The high-scoring students felt simulation use time was positively related to an increase in positioning skills, while the low-scoring students stated there was little or no increase in positioning skills related to simulation use time. It is interesting to compare these results with the actual amount of time students used the simulation program. Students were asked to spend at least 1 hour each week using the simulation. Those who complied with using the simulation for at least 1 hour each week showed higher scores on the survey than students who spent at most 1 hour each week using the simulation.

<u>Student – Tool – Outcome</u>

Students were asked in a general ways to share how they felt the simulation program affected their self-efficacy and the positioning skills. In this part of the interview they were asked follow-up questions to help explain or expand their answers. Many answers were repeated from the Rule – Student – Tool section but were further explored in this section of the interview.

There was a lot of overlap between the responses related to self-efficacy and the responses related to positioning skills. Students stated the two constructs were very related and dependent on each other, making it hard in some instance to differentiate between how the simulation program affected self-efficacy and positioning skills separately.

> Kimberly: I feel like you don't have very many skills and when you're not confident that you do know things, then you don't perform as well as you should.
>
> Interviewer: So, correct me if I'm wrong or I'm not wording it right, but it sounds like the impression that I'm getting is you feel that self-confidence and clinical skills are very related to each other and that they, while separate categories, they affect each other a lot.
>
> Kimberly: Yes

Interviewer: If you have a high self-confidence, then your skills are better. And if you have a low self-confidence then your, even if you've got the knowledge, your skills aren't as good.

Kimberly: I definitely feel that way. Because I think that anyone, even the smartest person, if you're not confident, you know what you're doing, you don't know how to properly utilize what you, even, if you know, you have it, if you're not confident in what you do, you still don't perform. Or like, I feel like people get burnt out and get lazy and they aren't confident. And so they just kinda like slough their way through things. And I think that confidence and skill sets are highly correlated.

Interviewer: Do you feel that it goes the other way too? Like if you've got better skills, skills that you are more confident.

Kimberly: I feel that way. Yes.

Given the nature of the two broad questions about how student felt the simulation program affected their self-efficacy and positioning skills, it is not surprising the common themes coded from this portion of the interview were *student self-efficacy* and *student positioning skills*. However, students also identified other themes in describing self-efficacy and positioning skills that were eventually coded into other themes as subthemes (see Figure 16). For example, the subthemes of *practice* and *simulation flexibility* were coded under *simulation characteristics*, but they also relate to how *student self-efficacy* and *student positioning skills* were affected. Discussing the themes of self-efficacy and positioning skills with the subthemes of other major themes will help to identify more specifically how students' use of the simulation program affected their self-efficacy and positioning skills.

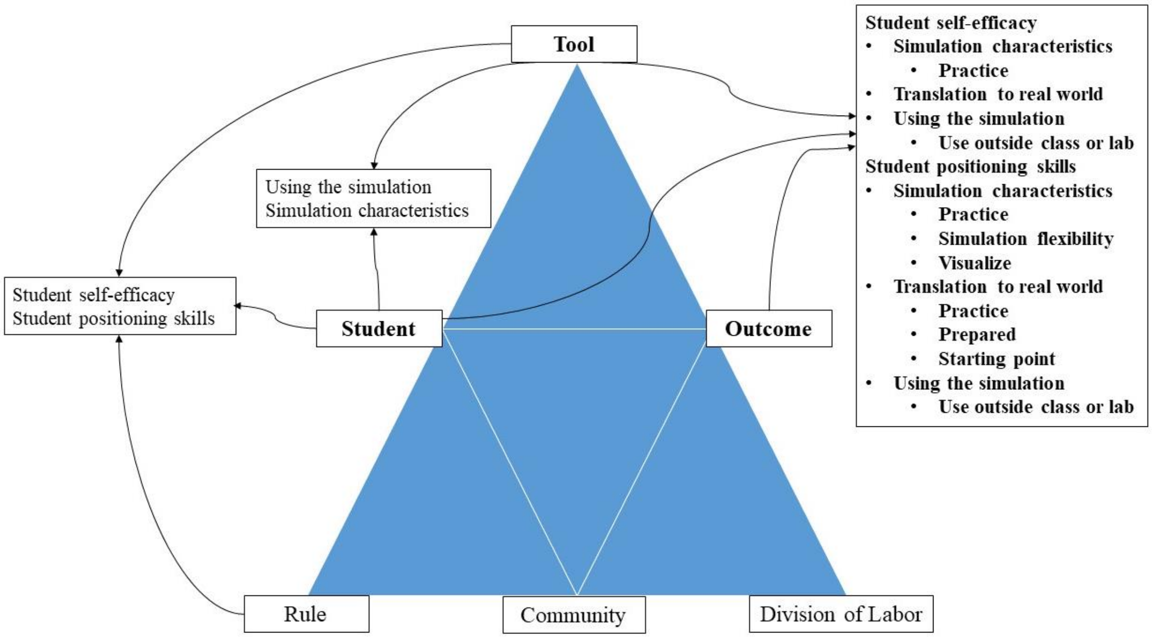

Figure 16. Student – Tool – Outcome Primary Themes

<u>Student Self-Efficacy</u>

Interview responses were mixed as to how the simulation affected the student's self-efficacy. Four students felt using the simulation positively affected their self-efficacy, while the other four didn't feel the simulation positively affected their self-efficacy.

Amelia: I feel like it made me more confident because I was able to go through all the steps in my head and it was easier to retain what it was supposed to be. So, yeah. I feel like once I got to clinicals and I had a patient there in front of me, I can remember my experience in the simulation software and it was easier to set up the patients that way. So overall I feel like it did increase my confidence in the clinical setting.

Elena: I think sometimes I got a little bit frustrated with it just because I felt like I couldn't do what I actually knew I could do, but, um, once I kinda got past that, I don't know if it really affected my confidence when it wasn't, when we're not talking about time, spent with it.

Surprisingly, this split was not divided between the four highest and four lowest STO scorers on the survey. One high STO scoring student didn’t feel the simulation positively affected their self-efficacy, while one low STO scoring student did feel a positive impact.

> Leah: (high STO score) It's tough. I don't have a lot of self-confidence. Um, it didn't really improve it much, I should say.

> Iris: (low STO score) Definitely it boosted on technical factors, manual technique for everything. Um, I like being able to go there with kind of technical factors in mind and then being able to work with the registered techs there. So I felt like that was part of what I kind of know, what would it be and then just expanding on that knowledge that I have.

As mentioned, students identified characteristics of using the simulation in regards to self-efficacy that were coded into other themes outside of *self-efficacy*. These attributes were coded under *simulation characteristics*, *translation to the real world*, and *using the simulation*.

<u>Simulation Characteristics</u>

Practice was the main subtheme identified under *simulation characteristics*. While more comments about practice were recorded in relation to positioning skills, students identified the ability to repeatedly practice with the simulation as an attribute which affected their self-efficacy. The virtual nature of the simulation program also overcame physical barriers travel and equipment, letting students practice at home and thereby increasing their self-efficacy.

> Kimberly: So that made me confident because I always had that, that fall back to be able to go and use the software if I felt like I needed extra practice, but I couldn't go to the classroom and where I live a whole hour away, like it's, it definitely improved my confidence in being able to be able to practice as often as I wanted.

Translation to the Real World

Students who reported an impact on self-efficacy after using the simulation stated they felt some of the self-efficacy they gained translated to the clinical setting. Students reported an increased performance in working with patients. They also reported the simulation gave them a starting point from which they could adapt real-life situations to. Both increased performance and having a starting point increased their self-efficacy.

> Amelia: I feel like it made me more confident because I was able to go through all the steps in my head and it was easier to retain what it was supposed to be. So, yeah. I feel like once I got to clinicals and I had a patient there in front of me, I can remember my experience in the simulation software and it was easier to set up the patients that way. So overall I feel like it did increase my confidence in the clinical setting.

Using the Simulation

Some students reported their ability to use the simulation negatively affected their self-efficacy. This is different from students stating the simulation negatively affected their self-efficacy. None of the students reported a decrease in self-efficacy from using the simulation; some reported their ability (or inability) to use the simulation negatively affected their perceived self-efficacy. Difficulties in learning how to use the simulation and some aspects deemed "non-user friendly" (e.g. manipulating the equipment or the patient, moving the avatar, etc.) kept some students from increasing in confidence. Still, none of the students reported a decrease in self-efficacy because of using the simulation.

> Jackie: Let's say that it did not really boost my self confidence.
> Interviewer: Okay. Anything else to add there about why or why not?
> Jackie: Um, just cause maybe just because I felt like it was just a little difficult to use, so it was just kind of in some points, it was just kind of like hard to keep moving on.

Another common subtheme under *using the simulation* was *using the simulation outside of class or lab*. Since the simulation was given to student to download and use on their personal computers or laptops, students could use the simulation whenever and wherever they wanted. This allowed students the flexibility to use the simulation at times convenient for them as opposed to scheduling a time to go to campus or clinicals and work around equipment availability.

> Kimberly: I definitely think that, um, it, it boosted my confidence a lot because like I was able to, to just do it in the comfort of my own home, if I wanted to, I could get on it at any time if I wanted to, if I needed to brush up on skills. And so like, I think that it definitely helped where I am [living], like so far away, it helped me be able to distance learn, but be a good utilization of my time.

Overall four of the students felt using the simulation positively impacted their self-efficacy while the other four reported no impact, neither positive nor negative. Some barriers prevented students from having a positive experience with the simulation in terms of affecting self-efficacy. Still, most students enjoyed the ability to use the simulation outside of traditional learning scenarios and the flexibility to practice what they wanted when they wanted and that the self-efficacy gained in using the simulation translated to the real-life clinical setting.

Student Positioning Skills

Responses to how using the simulation affected students' positioning skills were less mixed. Unlike the "Rule – Student – Tool" interview question where responses to use-time and positioning skills were split, more students reported using the virtual simulation positively affected their clinical skills, though the degree to which the skills were affected varied.

Iris: I feel like it did improve my skills, um, in producing better images and being able to know like my tendencies, um, where I usually do, I sent her a little bit lower, um, when I should actually be centering a little bit higher. I think that definitely helped my skills and being able to, you know, do the ALARA principle is, and try to get those images on the first try instead of, you know, like, okay, I think I'm there, let's shoot it. Um, but having more of a general like idea of my tendencies of what I tend to do.

Amelia: I feel like it helped, um, it did help me, like with the positioning or knowing where to put the, the two pet or like angling and stuff like that. So skill-wise, it did help because I had practiced them previously, even though it wasn't on a real patient, it's still like what's in my mind and I was able to gain better skills that way.

Students who stated less of an impact identified characteristics of the simulation that couldn't translate to real-life positioning skills.

Billie: I mean, it helped a little bit as far as like, you know, just the logistics side of being a tech, but there's a lot more to being a like patient care, dealing with like either a little kid or somebody that doesn't understand, or having to do like a portable or go into surgery or something. So I feel like it helped me a little bit, but there's lots of different parts about being a tech that it can't necessarily contribute to.

Only one student reported the simulation did not affect her clinical skills, but she stated she thought that was because of the little amount of time she actually used the simulation program.

As with self-efficacy, students identified characteristics of using the simulation in regards to positioning skills that were coded into other themes outside of *positioning skills*. These attributes were coded under *simulation characteristics*, *translation to the real world*, and *using the simulation*.

Simulation Characteristics

Similar to the *simulation characteristics* subtheme discussed under *self-efficacy*, *practice* was identified as an attribute of using the simulation that students found to be impactful for positioning skills. Being able to practice in a virtual environment without the physical restraints of a laboratory or clinical setting provided them the opportunity to develop and hone positioning skills without having equipment or patients.

> Kimberly: I feel like to be able to practice, practice, practice, um, you can never get better at anything unless you work hard to do so. And so I, I think that it definitely helped with clinical skills. Um, it built myself confidence to try to again, be able to relax, um, know that I know what I'm doing. And like, it, it just was a great tool to be able to practice.

The lack of *simulation flexibility* in the simulation program was identified as a barrier to developing positioning skills. The simulation program helped develop positioning skills in traditional or standard situations. Students identified a lack in patient body habitus variation and the inability to practice non-traditional exams and positions prohibited a greater effect on positioning skills.

> Interviewer: Okay. Um, when you said helped, helped a little with the logistics, what do you mean by logistics? Would you expand on that a little bit?
>
> Billie: Kind of like the textbook of like, this is what position you do for that, you know, if somebody orders in like a hand you're going to be expecting to do like three views, like practicing with those views. Um, mostly just like positioning how the X-ray should look and stuff like that. Whereas like situations you don't necessarily get a situation like this is like an older patient that can't hear you, like, how would you interact with them? It doesn't necessarily help with the things that change per patient, you know?

A third subtheme under simulation characteristics was the students' ability to *visualize* the exam. They noted the ability to see how they manipulated the patients' body position and the equipment as well as to develop a routine in performing a radiographic exam helped to improve their clinical skills.

> Jackie: Just cause like it was, it was helping me to see like it all laid out. So like step by step, it kind of helped. Ya know, just like maybe try to get a workflow down.

Translation to the Real World

Most students reported an increased in clinical skills when working with patients in a real-life setting because of the virtual simulation program. The simulation allowed them to *practice* manipulating the patient and the equipment, which helped translate to skills in the real world.

Interviewer:	How do you feel that using the simulation program affected your clinical skills?
Leah:	It improved it.
Interviewer:	How would you say it did?
Leah:	Let's see, just like knowing how to position the patient, the patient, getting the room set up. Um, all those minor things I should say that doesn't involve actually talking to the patient you get better at.

The simulation program help students feel more *prepared* to work with patients in a clinical setting. Students start the RS program with little or no knowledge or skills of how to perform radiographic exams. As noted, the simulation gave students a space to practice their skills and gain the experience they needed to work with real patients. Feeling prepared help students translate the skills they gained from using the simulation to radiographic exams with real patients.

Leah:	So I definitely feel like my skills, um, and being able to handle things like I handle them better and I don't, I don't know really how to word that. Um, but I feel like, like I've been able to build up on my skills [through using the simulation] because when we start this program, we are like thrown out there really fast. Like we have nothing and we're just “yeeted it out the door.” It's like, you feel like you don't have very many skills and when you're not confident that you do know things, then you don't perform as well as you should. Um, so I definitely think that it helped me to perform better in, in the clinical setting to be able to take on situations.

Students also commented that the simulation program gave them a *starting point* for their knowledge and skills. When in the clinical setting and when presented with non-traditional situations the skills they gained from using the simulation would gave them a base from which to adapt to the unique situation.

> Kimberly: And even if I didn't know what I was doing, I at least had a starting point. Like I could at least say, okay, this is what I know and build on that. And at least have somewhere to start rather than running around like a chicken with its head cut off being like, I don't even know what to do. So I think that the software gave me a little bit again of a fallback, um, on a set of skills that I knew I had so that I could then utilize them into other scenarios and situations in the clinical setting.

Using the Simulation

As with *self-efficacy*, the common subtheme of *using the simulation* was *using the simulation outside of class or lab*. Students found the simulation program useful in helping to develop positioning skills outside of normal class or clinical time. The same "anytime, anywhere" flexibility noted for *self-efficacy* were also noted for *positioning skills*. The simulation did not have some of the traditional limitations of developing positioning skills such as space and equipment availability.

> Elena: I think it helped a little bit with clinical skills because, um, yeah, it's just another opportunity to use those skills because X-ray is kind of unique that you can't use it everywhere. You can only use what you have X-ray equipment. So, um, it helps with clinical skills just by being able to practice.

Overall, almost all the students commented that the simulation program positively affected their positioning skills. While the simulation lacked flexibility in some aspects, the virtual nature of the simulation program afforded many opportunities for growth and development of positioning skills. Repeated practice and use outside of normal class or lab time help students feel more prepared to perform exams in a clinical setting, leading to a greater development of their positioning skills.

Student – Community – Tool

In the Student – Community – Tool portion of the interview, students were asked in what ways they used the simulation by themselves and in what ways they used the simulation with others (see Figure 17). Students were not given any instruction when they were introduced to the simulation as to how they should use the simulation by themselves or with others or for what purpose. The only instruction was to use the simulation for at least one hour each week. As noted in the survey results, most students preferred using the simulation program by themselves. In the interviews there was very little report of students using the simulation program with others.

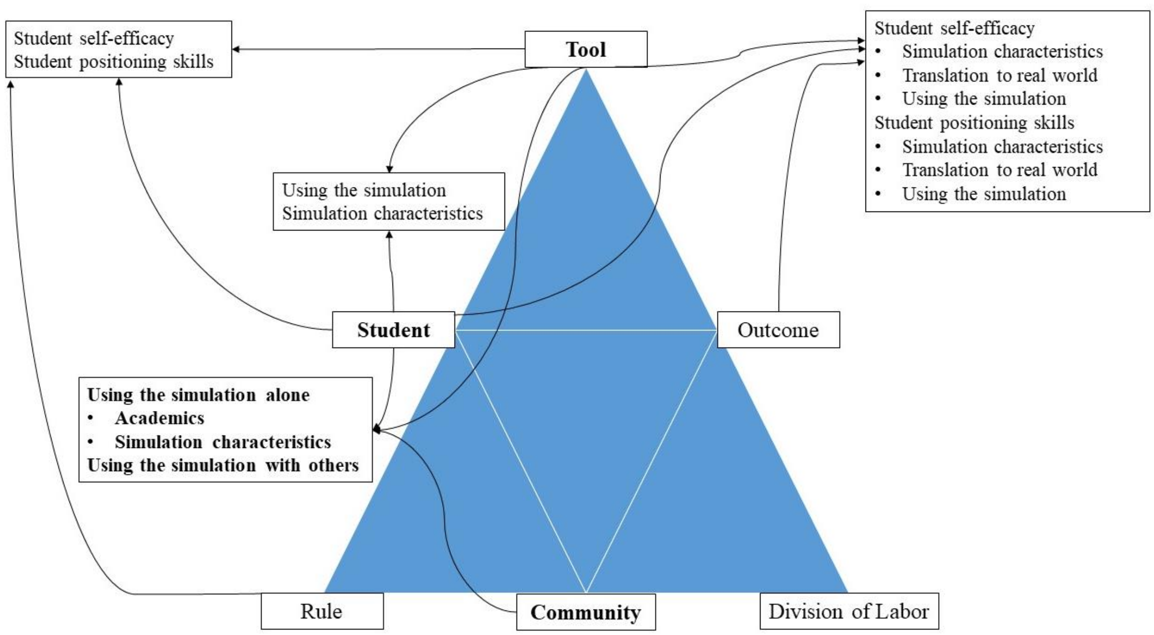

Figure 17. Student – Community – Tool Primary Themes

Using the Simulation Alone

Most of the students reported using the simulation alone. Of the students interviewed, all reported they primarily used the simulation by themselves. Students would use the program to practice radiographic positioning at home on their own time. One student commented that were she to be working with others, she would prefer to just physically practice positioning on the other people rather than using the simulation with them.

> Billie: Yeah. I think if I had gotten with a group, I would have preferred to actually try positioning on them, not necessarily using the simulation, if that makes sense.

Comments about students using the simulation by themselves was primarily coded into two major themes: *academics* and *simulation characteristics*.

Academics

The most common way students used the simulation by themselves was to practice for lab testing. Lab testing is an in-person simulation used as an assessment of students' radiographic examination positioning skills and knowledge. Students are assessed in lab tests multiple times throughout each semester. Lab tests are an assessment of a unit covering a specific body section (e.g. chest, abdomen, upper extremities, etc.) but are also cumulative to include any radiographic positioning exams on which the student has already been tested. The time students have to practice positioning in lab class is limited by lab and instructor availability. Students must use time outside of lab class to practice radiographic positioning in order to become proficient at performing these radiographic examinations.

> Student 1: I would practice for lab a lot. That was like the big purpose of me using it because in lab with [the instructor], we didn't have very much time to really practice. Like we practiced just once and then like the next week we had the test. So that was the biggest purpose on why I used it was to practice for lab testing and then therefore take it onto a clinical setting. Um, so by myself I would just go through positions that I needed to know, like when I was first learning chest X-rayed is I needed to know where to put the Bucky in relation to the patient and the collimator. Um, so I used it a lot just on specific positions that I didn't feel comfortable with.

Student 2: Um, I would just hop on and usually whatever positions we were preparing for, for a test, I would kind of go over and I'd have my notes from like lab of positioning and kind of do my best to like, remember what that looked like and do it on the, uh, simulation.

The majority of students stated they used the simulation by themselves in conjunction with instructional materials from the lab class to practice for lab tests. Using the simulation to practice for lab tests helped them feel better prepared and more comfortable with performing the radiographic exams.

Simulation Characteristics

The ability of students to practice radiographic positioning exams was identified as an important characteristic of the simulation. As noted, students used the simulation to practice for lab testing. Being a virtual simulation, students were able to repeatedly practice the same exam without constraints of physical space or time on campus. Students were also able to repeat exams without coordinating with other people to use as practice models and without the fear of possibly unnecessarily exposing patients to radiation. Virtual simulation also allowed the students to practice without fear of having real-world consequences in a repeatable environment.

Kimberly: I just used it at home by myself. In the ways I used it by myself, I mostly just took [the instructor's] like all of his lab handouts that he gives us and I looked at all the positions and I tried to see if I could do them. And then I tried to see if I could do them again. And then I tried to do another one and then go back and I just practice, practice, practice, all the different positions that were kind of on [the instructor's] handouts and saw how they looked and saw what I did and et cetera, et cetera.

Using the Simulation with Others

As noted, students primarily used the simulation at home by themselves. The flexibility of "anytime, anywhere" simulation use was hampered when trying to use the simulation with other students. The few comments students made about using the simulation with others were directed at how to use the simulation and overcoming technical and user error issues rather than practicing radiographic positioning.

> Elena: Um, yeah, I didn't use it with other people. [Another student and I] kind of talked about it once, just cause I was discussing the problem I had with a mouse and being able to view like the different views in turn in the room. Um, cause that was my initial problem, but it was pretty superficial conversation, I think for the most part.

> Kimberly: The only time we ever talked about it, really with other people was when me and [another student] didn't really understand it. And we didn't know how to make the guy move and we were kind of talking about it, but then we address that in class and like with you on a day and like, things were cleared up.

Some students noted they believed they could have seen more benefit to the program had they used it with other students. However, one student identified disadvantages of being required to use the simulation with other students.

> Amelia: I used it with someone just once and we were just both really struggling to figure out how to use it. Um, but that was the only time I've ever used it with other people. I feel like looking back, it would've been good to use it with other people cause we could have bounced ideas off of each other and we could have double checked each other's work because we all are studying the same thing. So I feel like in hindsight it would have been more beneficial to use it with other people.

> Billie: Um, I think it would have been good to ask other people because I remember when we talked about it one time in class, other people had figured out how to use it a little bit more smoothly than I had. And so I feel like I could have jumped through hoops, like through like the stumbling blocks of just figuring out the program itself if I had gotten together with more people.

> Kimberly: It's something that I, I think would be beneficial with people as a group, but then you run into some road blocks. There's a lot of people that don't like really group work or doing things as a group. And so like where it might be beneficial to some and some are like, I love doing it as a group. I feel like there's some that also would

be like, I hate doing it, doing it as a group; don't ever do that. Like, but I think that it would be something that might be, might be beneficial for people to, because you learn more when you do things with other people, in my opinion. And so I, I think that it would help to be able to learn the software as a group.

In general, students used the virtual simulation software by themselves. Though a couple of instances of student collaboration were noted, students only used the simulation with others to overcome technical and user error issues. Students primarily used the simulation to practice radiographic positioning in preparation for lab tests. Repeatability, versatility in what and how to practice, practicing at home, and a lack of real-world consequences were common themes identified as to how students found the simulation beneficial to use on their own.

Division of Labor – Student – Tool

The final portion of the semi-structured interview focused on the Division of Labor – Student – Tool intersection of AT. Students were asked if the software program provided enough instruction/administration to make it a valuable self-regulated learning tool and how their learning in class affected their ability to use the simulation program. A basic tutorial and demonstration of the simulation program was given to the students. The students were not given any other instruction as to how they were to use the tool.

Feedback regarding the simulation providing enough instruction to make it a valuable self-regulated learning tool was mixed. About half the interviewees felt the simulation did provide enough instruction, and half did not. Interestingly, there was no association between students' feelings about the simulation being a valuable self-regulated learning tool and their scores on the STO portion of the survey.

Iris: Yeah, I feel like it did. Um, cause they had it clearly across the top. Like everything that you would need to know for like your camera, the position, the body, the way that they were laying, like they had the dropdown menus, which was really helpful. Um, and they had written out very specifically, um, especially with positioning, like if the patient needed to be AP supine, like that was very clear. Um it's so you could kind of just toggle through that and if you didn't know exactly where you're going, you could just go through those menus and figure it out pretty quick.

Amelia: I personally felt like there wasn't enough instruction and it was just difficult to have to figure it out. I felt like I had to figure it out on my own and I would try and read the instructions and I felt like a lot of them didn't make sense or they could have been worded better. Um, overall I felt like it wasn't the best instruction wise.

Student feedback in this portion of the interview was wide and varied but mainly coded into the primary themes of *academics*, *simulation characteristics*, and *using the simulation* (see Figure 18).

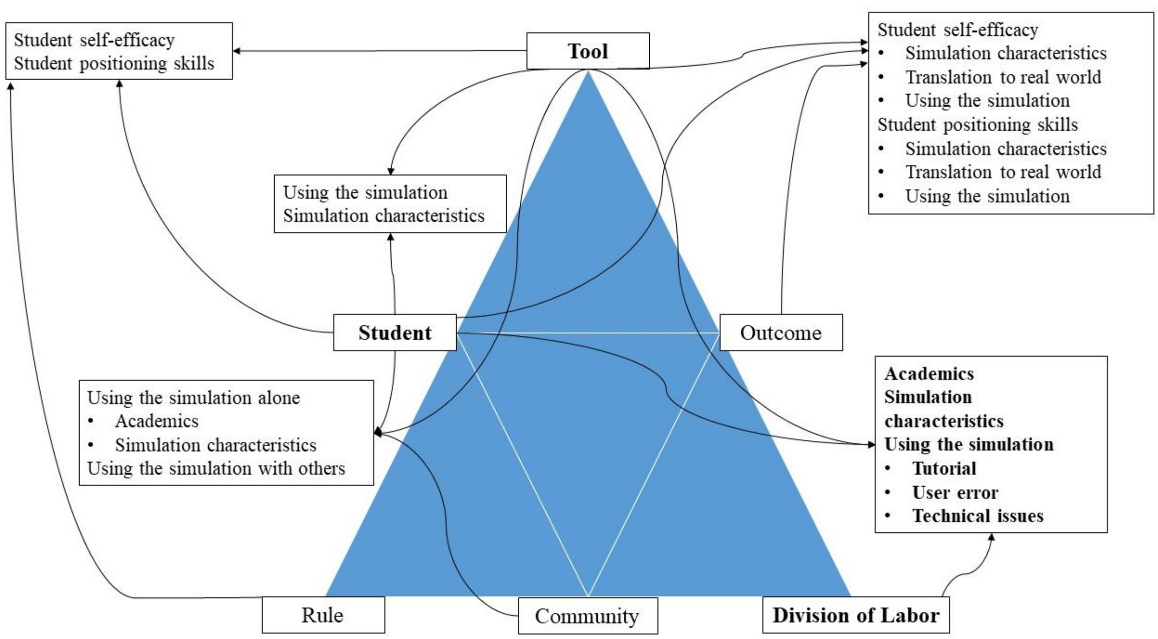

Figure 18. Division of Labor – Student – Tool Primary Themes

<u>Academics</u>

Almost all the students associated their use of the simulation program to *classroom instruction*. They stated that class is where they learned the information while the simulation is where they were able to practice and apply what they learned.

> Amelia: What [the] class gave me was like knowing what it was supposed to look like in person, knowing where the patient was supposed to stand or lay down. And so then I was able to figure out what I wanted in the simulation program, cause I was able to copy what we had done in lab.

> Leah: It improved my ability to use the program for sure. I had a better idea of what it was doing or what it was.
> Interviewer: Um, did you correlate a lot with class, like use the program to do things you were learning in class? Or was it kind of like, "Oh, I just want to learn how to do these other things?"
> Leah: I'd say I utilize what I learned in class for the program, not the program then class, if that makes sense.
> Interviewer: Okay. Were you ever doing stuff that you weren't learning about in class?
> Leah: No. I only focused on the things I learned.

> Elena: I relied a lot on the knowledge that [the instructor] had taught. Um, I wouldn't have been able to manipulate the program and figure out how to get the positions without having been taught that in school, I guess, unless I had really like cracked open a book and really wanted to study it and learn it on my own. Um, but yeah, I think that the classroom instruction, or just having someone show me, um, in real life was kind of a foundation to being able to use that. So I'm more used [it] to just kind of as practice. Yeah, I needed that initial knowledge from school.

One student used the simulation to practice radiographic positioning they had not learned yet in class. The virtual environment allowed the student to practice without real-world consequences and to experience exams she hadn't seen before. Because students were not given direction as to the ways they could use the simulation program, the student was not bound to only practicing the material they learned in class.

> Jackie: I wasn't practicing the things we were learning in [the instructor's] class. It was just something that I wanted to try just at random I

	have learned, but I wasn't trying like a skull or a spine just cause we hadn't learned those yet.
Interviewer:	Okay. So you used the program to practice things that you had learned about in class, but not necessarily what you would learn that week in class?
Jackie:	Ya, ya, exactly

Based on the feedback coded to academics, the positioning class and the associated instruction was an essential element when it came to using the simulation. The class provided a starting point from which students could then build their knowledge

Iris:	Well obviously just knowing, like having that base knowledge of what position, what, like, you need to be focused on that, obviously it's helpful because if you just kind of put your patient there and you can just start taking X-rays, um, you might not exactly know what you're looking for, but just knowing like they should be supine or they should be erect standing up against the wall Bucky, like that's obviously helpful to be able to get the images that you would have doing the same positions in, uh, your clinical settings.

Simulation Characteristics

As in the Student – Community – Tool section, multiple students commented on the ability to practice as a valuable characteristic of the virtual simulation program. The open nature of the "sandbox" environment let students engage in the activities they found most valuable, instead of being given a list of tasks to perform or objectives to accomplish. And although the students said they did not need objectives or additional regulation from the software program, the initial learning curve in orienting to the program's controls proved difficult.

Billie:	It was really helpful because I kind of had an idea of what I wanted to practice and I knew exactly like how it should look and where I should be positioning and kind of what I should be going for. Whereas if I just like gone into kind of fiddle around with it, I feel like I wouldn't have known if like the images were turning out how they're supposed to. So having that background of what I should be doing was great. So that, that was like the teaching base. And then

the simulation was more just practice rather than teaching me how to do it.

Elena: Yeah, I think it's good, um, as a self-regulated tool. Um, I didn't necessarily need objectives, but I think the initial instructions were kind of sparse. Like I was like, how do I get a patient? Like I couldn't figure that out initially. Um, once I got to that point though, I didn't need objectives. It was nice to just be able to practice and just work with it.

Using the Simulation

A common subtheme coded to *using the simulation* regarded a *tutorial* for the simulation program. Students were mixed in their comments as to whether or not the simulation program had an imbedded tutorial, but almost all comment on the need for one. Students felt that if there were a more in-depth tutorial to walk them through the steps of positioning for at least 1 radiographic exam that the skills learned in the tutorial would translate to being able to use the simulation more easily for other positions.

Kimberly: I don't remember if there was [a tutorial], and I feel like maybe there wasn't and that's why I was like, like running into the wall the whole time. I don't remember if there was a tutorial or a tutorial option and if I was just too lazy to do it, or if there wasn't one. Um, so I think that like, it was good and overall that the instruction was probably good, but if there's not a tutorial, that maybe one should be implemented because then it could be like, um, you're going to position for a SCAP Y and these are the keys and then kind of like walk you through it step by step. So you could at least be able to do one position and be like, alright, I understand the program. So now I can pretty much do whatever position, like, does that make any sense?

Another subtheme identified under *using the simulation* was students experiencing *user error and technical issues*. Some students had a difficult time translating the knowledge and skills they had learn in class and lab to performing radiographic positioning exams in the virtual simulation program.

Jackie: Well, they were tied together in the way that I knew, like if I was going to do a hand X-ray, like I knew how I was going to position the patient from [the] class. But when it comes to the simulation, I didn't know how to do it on there all the time. Or like put my patient in the position that I knew what I wanted to do.

Overall, students expressed that class was an integral part of their success when using the simulation program, and they depended on the skills and knowledge they gained in class and lab to properly perform radiographic exams virtually. Most student use of the virtual simulation was to practice what they were learning about in class. Students felt the simulation program was a valuable learning tool, but feedback was mixed as to whether or not the software program provided enough instruction and administration to be a valuable learning tool. Although a basic tutorial on how to use the simulation program was given to students in class, having a built-in tutorial, or at more in-depth tutorial embedded in the software, would have increased their user experience.

Summary of Findings for Research Question 2

Research question 2 focused on students' perceptions of their own self-efficacy and positioning skills after using a virtual radiography positioning software, MedspaceXR. Data was collected through individual, semi-structured interviews. The interview questions were developed to explain the items in the survey and aligned to explore the intersections of the key tenets of AT. The questions were determined before any interviews were conducted. All interviewees were asked all the predetermined questions; however, additional follow-up questions were asked as needed to help clarify responses, explore salient comments, and elicit more discussion.

Responses to the interview questions were coded using descriptive coding to assign a word or phrase to each sentence or paragraph of the qualitative data. These codes were then grouped together using the most frequent or significant codes to form primary themes: *student self-efficacy*, *student positioning skills*, *using the simulation*, *simulation characteristics*, *academics*, and *translation to the real world* (see Figure 19).

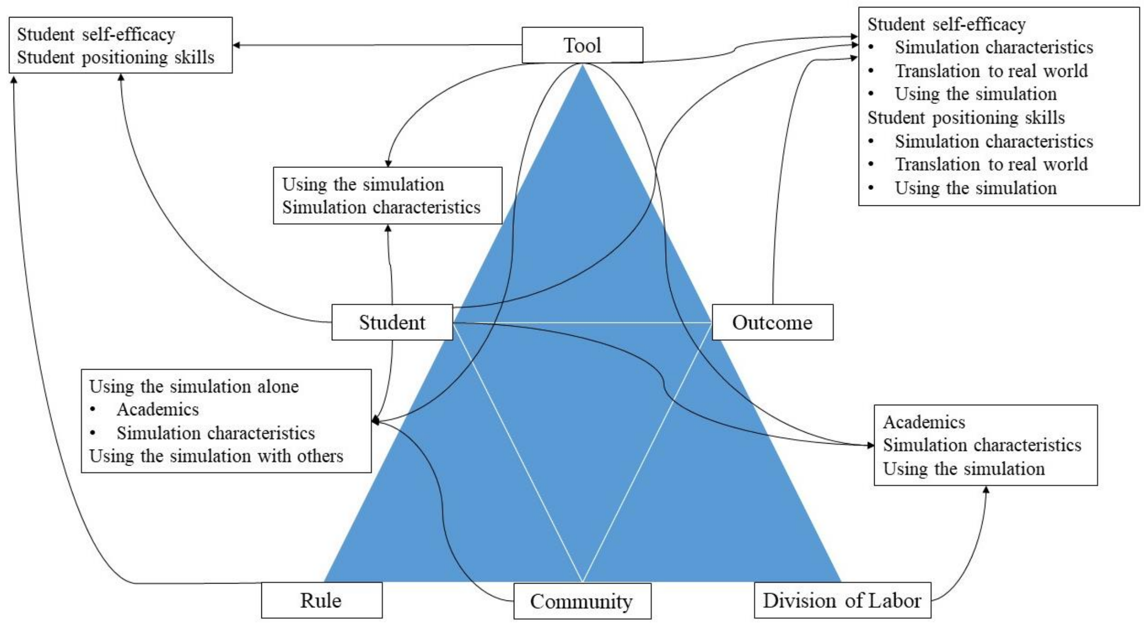

Figure 19. Activity Theory Interactions with Themes

Student comments about self-efficacy and positioning skills can be found in all sections of the interview data; however, they are primary concentrated in the Rule – Student – Tool and Student – Tool – Outcome sections. Overall students felt the more time they spent using the simulation program, the more their self-efficacy increased. Interestingly, only the high STO scoring students felt the more time they spent using the simulation program led to an increase in their positioning skills; the low STO scoring students felt the amount of time they spent using the simulation program did not affect their positioning skills.

Student perceptions were mixed as to the simulations effect on self-efficacy and positioning skills when irrespective of the amount of time students used the program.

However, unlike responses in the Rule – Student – Tool section, the mixed responses in the STO section of the interviews did not match the students' scores on the STO portion of the survey. Most students commented on the ability to use the simulation outside of traditional learning scenarios and the flexibility to practice what they wanted when they wanted and that the self-efficacy gained in using the simulation translated to the real-life clinical setting. Repeated practice and use outside of normal class or lab time also helped students feel more prepared to perform exams in a clinical setting, leading to a greater development of their positioning skills.

Since there was no requirement for students to use the simulation with others, most students used the simulation program solely on their own. The very few instances where students used the simulation with others were primarily for learning how to use the simulation program and not for learning or practicing positioning skills. Some students did comment that they thought using the simulation with other students may be beneficial for increasing self-efficacy and positioning skills, but the logistics of group work and shared equipment would pose their own problems.

Reports on the simulation providing enough instruction/administration to be a valuable self-regulated learning tool were mixed. The students depended on class and lab instruction to give them a basis for what they would practice when using the virtual simulation. All the students practiced what they were studying in class and as a preparation for lab testing. Some students also felt that technical problems made using the simulation difficult.

Chapter Summary

This chapter presented the quantitative and qualitative results of the research study. The data was presented through the framework of Activity Theory in relation to the research questions. The quantitative data presented the results of the survey instrument through descriptive statistics. In relation to research question 1, the survey data showed students reported more favorable than unfavorable outcomes of using the virtual simulation program in regards to their own self-efficacy and positioning skills. The qualitative data explored student feedback in interviews to identify common themes across the respondents. In relation to research question 2, students perceived their use of the simulation program either positively affected or had no effect on their self-efficacy and positioning skills. The major themes identified were “Student Self-Efficacy”, “Student Positioning Skills”, “Using the Simulation”, “Simulation Characteristics”, “Academics”, and “Translation to the Real World”. In Chapter 5, previous literature will be discussed as it relates to the findings, how the findings contribute to radiographic science knowledge, and implications for radiographic science educators and students.

CHAPTER FIVE: DISCUSSION

The purpose of this study was to investigate students' perceptions of their own self-efficacy and positioning skills after using a virtual radiography simulation in an undergraduate course. Self-efficacy and clinical skills were based on the perceptions of student evaluated through a survey instrument and follow-up interviews built on the tenets of Activity Theory (AT). The results indicate the majority of students liked using the virtual radiographic positioning software program (MedspaceXR), and they thought the program improved their self-efficacy and positioning skills. The following chapter will explore the data relevant to each research question and how that data compares to the available literature. This chapter will also discuss additional findings and limitations of the study.

Discussion of Research Question 1

The first phase of this ESR designed study focused on gathering quantitative data through a survey instrument. The survey instrument used in this study was adapted from the survey instrument used by Shanahan (2016a) to answer research question 1: What do students report as to their own self-efficacy and positioning skills after using a virtual radiography simulation program? This question relates to the survey instrument in the quantitative phase of the study. More specifically, the items under the Student – Tool – Outcome portion of the survey directly relate to self-efficacy and positioning skills.

<u>Self-efficacy</u>

Students reported the highest favorable responses to the criteria of "Encouraged me to think more about radiographic procedures" and "Encouraged me to think more about evaluating radiographic images." These criteria are tied to self-efficacy as self-efficacy is related to a person's perception of their ability to accomplish a specific task (Bandura, 1997). Thus higher scores for these criteria indicate an increase of self-efficacy after using the simulation program. Mason (2016) found an increase in students' self-efficacy scores and confidence level when setting up radiographic procedures. Increasing student confidence level in fundamental elements of radiography exams before students enter the clinical setting can make the transition from the university to the clinical practice less stressful for students (Mason, 2016; Shanahan, 2016a).

These findings align with others researching the clinical preparedness of RS students. Common pedagogical themes including active learning, motivation, case-based studies, reflection, situations which require critical-thinking skills, objective structured clinical examination, and engagement activities are tied to self-efficacy and increased clinical preparedness (Holmström & Ahonen, 2016; Marshall & Harris, 2000; Sedden & Clark, 2016). "Think more about radiographic procedures" and "think more about radiographic images" fall under pedagogical themes identified by these researchers. Varied and personalized simulation experience, such as MedspaceXR, can help students develop critical thinking skills in a safe learning environment (Holmström & Ahonen, 2016; Marshall & Harris, 2000; Sedden & Clark, 2016).

The lowest reported responses under self-efficacy on the survey was to the criterion "Had a positive effect on my ability to self-evaluate when I evaluate radiographic images." This result is not unexpected as students were asked to use the simulation to focus on positioning skills rather than image evaluation. Still, even though this criterion received the lowest average score in this section, the score was still more positive than "neither agree nor disagree." With more emphasis on image evaluation when students use the simulation in the future, they may see greater benefit to using the simulation for image evaluation. Virtual simulation has already been identified as a useful tool for image evaluation by radiologists (Sabir et al., 2014), so radiographic science students may benefit as well.

Positioning Skills

The greatest favorable responses in the positioning skills section of the survey were "Helped me learn as I was able to repeat activities until I was satisfied with the result" and "Had a positive effect on my ability to set up a radiographic examination." Both directly relate to positioning skills as they refer to manipulating radiographic equipment and physically preparing for an exam. Repeatable activity and practice are characteristics of virtual simulation favorable to education and learning. Virtual simulations provide a scalable, convenient method for students to repeatedly practice clinical skills in a safe environment (Berry et al., 2007; Olxaewski & Wolbrink, 2017; Shanahan 2016a). The safe and risk-free environment offered through simulation gives students the ability to practice health care skills without endangering patients (Berry et al., 2007; Cook et al., 2012; Gordon et al., 2004; Kasprzak, 2016; Kong et al., 2015).

Like students reported on the survey of the current study, Shanahan (2016b) also reported virtual simulation increased students' ability to set up radiographic procedures. The students reported they believed that using a virtual simulation for exam setup translated to increased clinical performance in the real world. Enhancing technical skills through virtual simulation can allow students to concentrate on other skills that can only be obtained in the clinical setting (Bridge et al., 2016; Shanahan, 2016b).

The lowest reported score in the positioning skills portion of the survey was a criterion very similar to the lowest scored criterion of the self-efficacy section: "enhanced my image evaluation skills." Again, this result is not surprising as image evaluation was not an area of emphasis of this study nor in the instructions given to students on how or in what ways to use the virtual simulation program. Like its self-efficacy counterpart, this criterion still showed a more favorable than unfavorable score, though it was the lowest score in this section. Still, students' skills in assessing image quality can increase after using virtual simulations, which is a key factor in determining the diagnostic acceptability of images (Ahlqvist et al., 2013; O'Conner et al., 2020). Determining diagnostic acceptability of images is an essential duty of radiographers.

Summary of Discussion on Results for Research Question 1

Students reported more favorable than unfavorable outcomes of using the virtual simulation program in regards to their own self-efficacy and positioning skills. When students can develop and enhance positioning skills in the pre-clinical environment, they can use their clinical time to focus on developing skills and experiences that can only be obtaining in a real-life clinical setting (Bridge et al., 2016; Shanahan, 2016b). Other studies performed to assess radiography students' self-efficacy and positioning skills after using a virtual simulation have shown similar and even stronger results (Mason, 2016; Sedden & Clark, 2016; Shanahan, 2016a; Shanahan, 2016b). Though evaluating image quality was not part of this study, it is an essential function of radiographers. Other studies have shown virtual simulation can be a valuable tool in helping students acquire image evaluation skills (Ahlqvist et al., 2013; Papamichail et al., 2014; Shanahan, 2016a).

Discussion of Research Question 2

The second phase of this ESR designed study focused on gathering qualitative data through individual interviews with students. The semi-structured interviews asked questions based on the survey instrument and the salient intersections of AT to answer research question 2: What are students' perceptions of their own self-efficacy and positioning skills after using the virtual radiography simulation program? Though the five intersections of AT can help give context to understanding student perceptions of using the simulation, the feedback under the Rule – Student – Tool and Student – Tool – Outcome sections of the interviews directly relate to self-efficacy and positioning skills. These two sections specifically ask questions (in the survey and the interviews) about students' perceptions of their self-efficacy and positioning skills students' after using the virtual simulation.

Rule – Student – Tool

In the Rule – Student – Tool portion of the interview, students were asked how the amount of time they spent using the simulation affected their self-efficacy and positioning skills. As would be expected students reported the more time they spent using the simulation, the greater positive impact it had on their self-efficacy. Student engagement with a virtual simulation program enables their self-efficacy in performing positioning skills to be higher than those that are not as engaged (Gunn, Rowntree, Starkey, & Nissen, 2020). The more the students used the program, the more familiar and comfortable they became with the program; the more familiar and comfortable they are with the program, the less technology and time barriers keep students from practicing and learning, allowing their self-perception of their ability to accomplish positioning tasks to increase (Burden et al., 2012; Gunn et al., 2020; St. John-Matthews et al., 2013).

Not all students reported similar perceptions of the virtual simulation's effect on positioning skills in relation to time spent using the simulation. Some students reported the more time they spent using the simulation program the more their positioning skills increased. These students spent the most time using the simulation and who had the highest STO scores from the survey, similar to results found by Gunn et al. (2020). Students with low STO scores reported to have used the simulation less. To ensure students use a virtual simulation program for enough time to see a benefit to their positioning skills, educators may need to establish some form of incentive to get students to comply. Coerced incentives, such as tying participation to a grade through required participation, instructor-led exercises, or pre- and post-test scores (O'Conner et al., 2020; Shanahan, 2016a), or persuaded incentives, like extra practice time and bonus points on an assessment (Gunn et al., 2020; Shanahan, 2016b), can help motivate students to spend the time necessary to see an increase in positioning skills through using the virtual simulation program.

Student – Tool – Outcome

The Student – Tool – Outcome portion of the interviews focused on how students used the tool and how doing so affected their self-efficacy and positioning skills. All the student reported overlapping results between the effect on self-efficacy and the effect on positioning skills. Virtual simulation allows students to practice technical skills which led to increased student confidence (Bridge et al., 2007; Bridge et al., 2016; Green &

Appleyard, 2011). Increased self-efficacy, or a student's own perception of their ability to properly position patients for radiographic exams, also leads to higher clinical performance (i.e. positioning skills) (Mason, 2006; Shanahan, 2016b). Therefore, self-efficacy and positioning skills are interrelated.

STO Self-Efficacy

Students, independently of their scores in the STO portion of the survey, present similar perceptions regarding self-efficacy impact in the interviews. This result differs from other studies about radiographic science student self-efficacy after using a virtual simulation. In other studies, students survey scores were similar to interview feedback (Gunn, Jones, Bridge, Rowntree, & Nissen, 2017; Gunn et al., 2020; Shanahan, 2016a). The current study's differing results could be due to research inexperience or the students' misinterpretation of the interview question. The most common themes coded from the interviews in this section were "practice," and "difficulty in using the simulation."

Practice

The ability to practice radiographic positioning exams was stated by students as major factor which increased their self-efficacy. Students stated the ability to repeatedly practice positioning as much as they wished, combined with an open simulation environment and a lack of real-world consequences, improved their own perception of their ability to complete radiographic exams on their own. Students also reported the ability to use the simulation outside of regular class or laboratory practice time contributed to their self-efficacy. Virtual simulation can help augment or supplement traditional lab practice time, because students aren't limited by space availability or coming to campus.

These same ideas are noted throughout simulation research literature. The safe and risk-free environment offered through simulation gives students the ability to practice health care skills without endangering patients (Cook et al., 2012; Kasprzak, 2016; Kong et al., 2015; Shanahan, 2016a). Virtual simulations can provide a scalable, convenient method for students to practice clinical skills in a safe environment (Berry et al., 2007; Kasprzak, 2016; Olxaewski & Wolbrink, 2017). In addition, virtual simulation leverages learning theories for adult learners through self-pacing and the ability for repetition, and on-demand accessibility to education at the convenience of the student (Cook et al., 2012; Kong et al., 2015; Olxaewski & Wolbrink, 2017).

Difficulty in Using the Simulation

Students who reported that it was sometimes difficult to use the simulation stated these barriers negatively impacted their self-efficacy. Some even reported a lower self-efficacy because of these difficulties until they were resolved. Some reported barriers to using virtual environments within higher education have included challenges using technology and institutional and personal perceptions (Gregory et al, 2015; Gunn et al, 2020; King et al, 2018). Such difficulties include the "user-friendliness" of the simulation program, unfamiliarity with the user interface, and a lack of experience manipulating an avatar in an on-screen virtual environment. One student reported she could not manipulate the avatar how she desired, which made her frustrated and decreased her self-efficacy; she ultimately overcame this challenge through time and practice.

If these challenges are not overcome, students' self-efficacy can decrease and lead to them refusing to use the simulation. Wagner (2017) found the technical barriers and difficulty in using a simulation became so great that she was unable to complete her study of radiographic science students using a virtual simulation because the students refused to continue with the study. Students should be given adequate support through tutorials and trainings when being introduced to a virtual simulation program. The introduction of new simulation software can cause technical difficulties which may diminish learning opportunities (Burden et al., 2012; James et al., 2012; St. John-Matthews et al., 2013).

STO Positioning Skills

All the students in this study reported an increase in their positioning skills after using the virtual simulation, though the degree of increase varied among the students. This same relationship is found throughout virtual simulation research. Students cited the safe learning environment of virtual simulation allowed them to develop their skills without endangering patients, provided the ability to make and learn from mistakes, and decreased time pressure that occurs in the clinical environment as factors which led to their increased performance (Bridge et al., 2007; Bridge et al., 2016; Green & Appleyard, 2011; Shanahan, 2016a). Though not specific to medical imaging, similar benefits of narrowing the gap between psychomotor skills acquisition and clinical practice were found when using virtual simulation in certain surgical education trails as well (Berry et al., 2007; Densen, 2011; Gordon et al., 2004; Tjiam et al., 2014). The most common themes coded from the interviews in this section were "practice," "lack of flexibility," and "visualize."

Practice

As with self-efficacy, the ability to practice radiographic exams using the virtual simulation was identified as having a large impact on positioning skills. The virtual simulation program allowed students to repeatedly move, manipulate, and align radiographic equipment in an exam setting. Students were also able to manipulate the virtual patient to position them for various radiographic exams (e.g. chest, abdomen, spine, extremity, etc.). Fears of making mistakes or overexposing a patient were removed because of the virtual nature of the simulation program (Gunn et al., 2020; O'Conner et al., 2020). Virtual simulation also provides a training scenario that is less awkward than students practicing on study participants or patients (Burden et al., 2012; Coline et al., 2015; Lemheney et al., 2016; Shanahan, 2016a). All steps of equipment, exposure factor, and patient manipulation had to be completed before a radiograph could be produced. While no amount of simulation (real-life or virtual) can replace clinical experience, enhancing technical skills through virtual simulation can allow students to concentrate on other skills that can only be obtained in the clinical setting, such as patient care and communication skills (Bridge et al., 2016; Shanahan, 2016b).

Lack of Flexibility

Students stated the lack of flexibility in the simulation program decreased their ability to improve their positioning skills. The simulation only offered one simulated patient: a seemingly healthy and very compliant young-adult Caucasian male. Often in the clinical setting, real-life patients have one or more conditions that decrease their ability to comply or to move. Geriatric, bariatric, and pediatric patients may have physical or mental conditions which restrict their ability to understand and comply with instructions or to move body parts in ways necessary to complete a radiographic exam. Trauma patients often require alternative or non-typical positioning techniques. All these scenarios were not able to be replicated in the virtual simulation. Others researching virtual simulation have not mentioned the lack of flexibility or diversity in the patients presented in simulations. This may be because other simulation programs have patient variations not available in MedspaceXR, or the researchers may not have explored or collected data related simulation flexibility.

The lack of physical touch was also a barrier to developing positioning skills. Radiographers are required to palpate patients for bony landmarks which they use to align the patient with radiographic equipment. This element of realism in relation to key aspects of patient positioning, such as the inability to palpate bony landmarks and a lack of patient interaction, decreased students' ability to develop positioning skills when using the virtual simulation (O'Conner et al., 2020; Shanahan, 2016a). Proper communication and interaction with patients is required to gain consent to touch patients and put them at ease when palpating for these landmarks and manipulating body parts for an exam.

Visualize

The virtual simulation is inherently a visual process. The virtual environment is displayed on a computer screen, and student interact with the virtual environment by choosing and manipulating equipment and the patient. The requirement to visualize the virtual simulation could pose a major barrier for people who are visually impaired. Still, students in this study reported the ability to see and visualize the exam as well as the resultant radiographic image helped develop their positioning skills. Specifically they stated seeing the exam through the virtual simulation help them learn more and be better prepared for the clinical setting than did imagining the exam in their minds or reading about it from a textbook. Findings in this study match the literature in that students could compare their virtually generated radiographic image with the correctly positioned "ideal image", thus providing instant feedback to enable them to learn from their mistakes (Gunn et al., 2018; O'Conner, et al., 2020; Shanahan, 2016a; Shanahan, 2016b).

Summary of Discussion on Findings for Research Question 2

Overall students enjoyed using the simulation program and found using it increased their self-efficacy and positioning skills. The degree to how much their self-efficacy and positioning skills increased was influenced by the amount of time the spent using the simulation. The ability to virtually practice radiographic exams in a safe, risk-free environment was stated as the most common favorable feedback for both self-efficacy and positioning skills, which is also seen in the literature (Bridge et al., 2016; Gunn et al., 2020; Green & Appleyard, 2011; Shanahan, 2016a). Similar to other research findings, being able to see the exam, equipment, and the ideal image was also stated as a great benefit of the simulation program (Gunn et al., 2018; O'Conner, et al., 2020; Shanahan, 2016a; Shanahan, 2016b). Technical barriers of unfamiliarity with using the virtual simulation and an awkward user interface inhibited students' ability to use the simulation program, but these obstacles were mitigated by using the simulation more. The lack of flexibility in the simulation program, both in the virtual patient and in the ability to manipulate the virtual equipment, was identified as a shortcoming of the simulation (O'Conner et al., 2020; Shanahan, 2016a). Still, students overall reported a positive experience using the virtual simulation that led to improved self-efficacy and positioning skills.

Analyzing Research Question 1 and Research Question 2 Together

RQ1 investigated students' self-reported positioning skills and self-efficacy scores collected through a survey instrument; RQ1 collected quantitative data. Students with the 4 highest and 4 lowest average score on the STO portion of the survey were selected for interviews. RQ2 further explored students' perceptions of their own self-efficacy and positioning skills in individual interviews with the researcher; RQ2 collected qualitative data.

Using qualitative interviews to explain quantitative data provides a stronger support for conclusions drawn from the collected data than either method used individually. The rationale for mixing both types of data is that neither quantitative nor qualitative methods are sufficient by themselves to capture the trends and details of situations, such as the complex issue of radiography students' preparedness to enter the clinical setting. When used in combination, quantitative and qualitative methods complement each other and provide a more complete view of the research problem (Greene, Caracelli, and Graham, 1989; Johnson and Turner, 2003; Tashakkori and Teddlie, 1998). There were both areas of convergence and divergence between the data collected from RQ1 and RQ2. A summary of the findings are found in Table 12.

Table 12. Summary of RQ1 and RQ2 Convergence and Divergence

Relative to Time Usage	
Self-Efficacy • Regardless of STO survey score, all students stated an increase in self-efficacy • STO score increased as reported time use increased	Positioning Skills • 4 students stated an increase in positioning skills, 4 stated no change • STO scores matched feedback: top 4 STO scoring students saw an increase, bottom 4 students saw no change
Irrespective of Time Usage	
Self-Efficacy • 4 students reported an increase, 4 students reported no change • Students in these 2 groups did not align to the high and low STO score groups	Positioning Skills • 7 students reported an increase, but varied by how much • Reports of increase did not correlate to STO score • 1 student reported no change, cited limited use time

Results Relative to Time Usage

Student self-reported perceptions of the simulation's effect on their self-efficacy was that the amount of time they spent using the simulation positively affected their self-efficacy for all students interviewed. The degree to how much self-efficacy increased was directly related to the amount of time the student spent using the simulation. As their use time increased, so did their STO score on the survey and their self-reported impact in the interview. These same results were found by others researching virtual simulation use in radiographic science (Gunn et al., 2017; Gunn et al., 2020; Shanahan, 2016a; Shanahan, 2016b).

Student self-reported perceptions of the simulation's effect on their positioning skills was not the same for all the students. Students with the 4 highest STO scores all stated that the amount of time they spent using the simulation positively affected their positioning skills; the more they used the simulation, the more their positioning skills increased. This is not the case for the students with the 4 lowest STO scores. The 4 lowest STO scoring students stated the amount of time they used the simulation had no effect on their positioning skills. This finding contradicts current literature where students in other studies stated the more they used a virtual simulation, the greater their positioning skills increased (Gunn et al., 2017; Gunn et al., 2020; Shanahan, 2016a; Shanahan, 2016b).

Irrespective of Time Usage

When asked to consider the effect virtual simulation had on their self-efficacy when not taking into account how much they used the simulation, student perceptions were split. Four of the students reported using the simulation positively affected their positioning skills while 4 students reported no change. What is interesting is these self-reported findings in the interviews do not match the STO scores from the survey; the 4 students who reported an increase in self-efficacy were not the 4 highest STO scoring students, and the 4 students who reported no increase in self-efficacy were not the 4 lowest STO scoring students. Again, this finding does not match the current literature in that overall students reported a higher self-efficacy after using a virtual positioning simulation program (Gunn et al., 2017; Gunn et al., 2020; Shanahan, 2016a; Shanahan, 2016b).

Student self-reported perceptions of the simulation's effect on their positioning skills was similar for almost all the students interviewed. When simulation use time was not considered, 7 of the students reported their positioning skills increased after using the simulation. The degree to how much the simulation increased their positioning skills varied among the students, with no discernable or common measures outside of time usage. One student reported no change in positioning skills after using the simulation, but specifically cited limited simulation time usage as the main reason for this perceived lack of impact. These findings are consistent with the current literature; using a virtual simulation had a varied but positive effect on positioning skills (Gunn et al., 2017; Gunn et al., 2020; Shanahan, 2016a; Shanahan, 2016b).

Additional Findings

Outside the scope of the research questions, there were a number of other findings in this study. Students had a strong connection between what they learned in class and lab with how they used the virtual simulation. Therefore it is essential that radiography educators find ways to use sound pedagogical techniques when incorporating a virtual simulation program into a radiography curriculum. Students felt the simulation was a good supplement to classroom and lab instruction rather than a replacement. The content of the classroom and laboratory course was considered effective, well structured, and relevant; however, the students found the virtual simulation would make a better supplement to lecture content rather than a stand-alone tool (O'Conner et al., 2020; Papamichail et al., 2014). The method with which the simulation is effectively integrated influences the simulation's association with higher learning outcomes (Cook et al., 2012).

Overwhelmingly, students in this study stated if given the choice they would rather practice radiographic exams in person to improve their self-efficacy and positioning skills. This response was not a surprise; many of the barriers to using virtual simulation identified in this study can be overcome simply by practicing radiographic positing exams in a laboratory or clinical environment. However, this stance differs from other studies in which simulation had been shown to increase student satisfaction and learning when compared to traditional teaching methods (Bauman & Ralston-Berg, 2015; Olxaewski & Wolbrink, 2017; Shanahan, 2016a).

Students experienced unforeseen technology issues. These issues are beyond user error and familiarity with using the simulation program. For one student the virtual simulation program greatly drained her laptop battery after she downloaded the program. The decreased battery power required her to constantly have her laptop plugged in when she used the virtual simulation program; fortunately, she stated this requirement did not impact her self-efficacy or positioning skills after using the simulation, but that is was only a minor annoyance. For another student, a large barrier was that MedspaceXR was only compatible with Windows© operating system; the student only had macOS© operating devices. This barrier required the student to use the simulation on campus in a computer lab, greatly limiting her ability to use the simulation program and the effect the simulation had on her self-efficacy and positioning skills.

Students made many comments about the ability see the ideal X-ray image in the simulation program. In traditional laboratory practice time, students are given feedback by instructors and other students on their radiographic positioning skills for the specific exams they are practicing. The instructors also explain to students why their positioning would or would not produce a quality radiographic image; however, students do not then produce the radiographic image because doing so would unnecessarily expose others to ionizing radiation which can cause biological damage to living tissue. Because students do not produce radiographic images in a laboratory setting, they get very little experience evaluating radiographic images in a controlled, low-stakes learning environment. In retrospect it is not surprising that students overwhelmingly commented on the ability to compare their virtually produced radiograph to an ideal image and position because they are not given this opportunity in the real world without working with real patients in a clinical setting. Others studying radiography virtual simulation have noted similar students' positive comments on the ability to virtually produce a radiograph and compare it to an ideal image (Gunn et al., 2017; Shanahan, 2016a; Shanahan, 2016b). However, this result was an unexpected finding as the purpose of the current study was to investigate self-efficacy and positioning skills and not the resultant radiograph.

Limitations

There were a number of limitations to this study. The sample size (i.e. 13 first-year RS students) was of convenience and was small in number. With convenience sampling, the researcher cannot say with confidence that the sample is representative of the population. And, specifically with MMR, "inadequate sample sizes limit the degree to which appropriate meta-inferences can be drawn from conclusions based on both phases of the study" (Tashakkori & Teddlie, 1998, p. 361). In addition, Creswell and Plano-Clark (2018) stated, "Quantitative results can net general descriptions of the relationships among variables, but the more detailed understanding of what the statistical tests or effect sizes actually mean is lacking" (p. 13). However, the sample still provided useful information for answering the research questions (Creswell, 2014). The effects of combining qualitative and quantitative approaches are synergistic, meaning the amalgamation of the two traditional approaches can be more valuable than each can individually (Creswell, 2014; Hall & Howard, 2008). Research problems best suited for a mixed methods approach are those where one source of data may not be sufficient or where results need to be explained (Creswell & Plano Clark, 2010). Such is the nature of virtual simulation research. Therefore, though the cohort size was too small for a strong, rigorous statistical analysis, inferences were drawn through both the quantitative and qualitative phases of the study. The use of an MMR approach helped to strengthen the conclusions drawn more so than individually analyzing just the quantitative or qualitative data.

The introduction of new simulation software can cause technical difficulties which may diminish learning opportunities (Burden et al., 2012; James et al., 2012; St. John-Matthews et al., 2013). Also, some studies have shown the use of computers is associated with gender and age differences (Huffman et al., 2013; Teo et al., 2015). Technical difficulties of using the virtual simulation may influence students' perceived effect of the intervention. Inexperience in using MMR may have limited the study's design, implementation, and interpretation. Little research exists on the efficacy and effectiveness of commercially available simulation programs for RS positioning practice. There was also limited precedents to follow for designing and executing a plan to use virtual simulation in RS curricula.

This study was not able to investigate the impact of other factors on students' self-efficacy and positioning skills. These other factors could include gender, age, and technology skills. Since all the participants in the survey and in the interviews were female, there was no way to evaluate the virtual simulation's effect on self-efficacy and positioning skills as a function of gender. Other studies have explored the relationship between technology self-efficacy and gender roles among university students, finding males report higher levels of self-efficacy in their own computing skills and competence than females (Huffman et al., 2013; Teo et al., 2015; Shanahan, 2016a).

The impact of student age on self-efficacy and positioning skills after using the simulation was not able to be evaluated in this study. Age ranges of the participants was 20-27, a fairly homogenous group. Correspondingly, all the participants by virtue of their age would be considered digital natives. Technical skills as a function of age or tech savvy were not evaluated as part of this study, as they have been in other studies (Helsper & Eynon, 2010; Shanahan, 2016a).

The study's timing and timeline may have impacted the students' experience and perceptions, therefore impacting the findings of this study. Students were given the simulation to use during the Fall 2019 semester. Students completed the survey in December 2019 at the end of the semester. Being the end of the semester with all the deadlines, additional stress, and final examinations given during that time may have impacted what students reported on the survey. In March 2020, the COVID-19 pandemic interrupted the regular course of the Spring 2020 semester. Students were unexpectedly moved to online instruction and were not allowed to attend clinicals. The interviews for this study were conducted in April 2020 via Zoom. The experience of abruptly moving to online and distance learning education may have impacted students perceptions of computer-based simulation or the way they remembered using the simulation.

Another limitation of this study was the relationship between the researcher and the participants. I had a close relationship with those who answered the survey and participated in interviews by nature of me being one of their instructors in the Radiographic Science program. This relationship may have affected the scores they reported and their shared perceptions in the interviews. Students may have over-reported their positive perceptions, either consciously or unconsciously, because of the nature of our student-instructor relationship.

Future Impacts

This study and other studies have shown virtual simulation can have a positive impact on students; however, as previously identified, the manner in which virtual simulation is integrated into existing curriculum is crucial. Students need motivation and "buy in" to make using a virtual simulation meaningful. As they see the benefits of using a virtual simulation and/or as they use the simulation to fulfill coursework requirements, they will be motivated to overcome challenges inherent in using a simulation program, such as a technical user interface, user error issues, and converting 3D skills and knowledge to a 2D virtual environment.

As the educator who implemented the virtual simulation into radiographic science curricula, I would use this simulation program again. I would have students use it to help prepare for laboratory testing and to help improve self-efficacy and positioning skills which translates to being better prepared for the clinical setting with real patients. However, I would tie practice time in the simulation to some sort of consequence, either positive (e.g. extra credit on an assignment or laboratory testing score) or negative (e.g. making simulation use time required or having students take screenshots of required radiographic positioning exams to prove they used the simulation). The method I used in this study was to simply explain the benefits of using the program and asked students to use the simulation. I assumed they would see the inherent value in the simulation program and use it of their own volition. I can see this benefit as an educator; however, looking back at my own experience as a student, I don't know as I would have used the simulation had there not been some kind of consequence.

It would also be very beneficial to tie instructions or requirements for using the simulation to what students are learning in the classroom and laboratory sessions. This idea was stated by students in this study as to how they used the simulation program: they associated what they were learning with how they used the simulation. I would recommend to educators in the future that they make a checklist of requirements students should complete in the simulation program that align with the unit, chapter, or module they are covering in class. Giving students something to focus on while using the simulation will help keep them motivated and on task as opposed to students being aimless in their simulation use or being overwhelmed with all the possibilities the simulation has to offer.

Virtual simulation offers unique abilities to learn positioning skills and the confidence to complete them. The only other way students can develop these skills and confidence is through laboratory practice and clinical time working with patients. As noted the limitations of these other learning experiences is limited; virtual simulation offers another option for students to acquire positioning skills and improve self-efficacy. While there are many limitations to using virtual simulation, such as learning the user interface and difficulties translating skills and knowledge to manipulating a virtual avatar and equipment, I believe the benefits outweigh these limitations. There is still value in using virtual simulation as a means to developing skills and self-efficacy. As computer/processing equipment and virtual simulation software, so, too, will people's ability to use these technologies.

Implications

The findings for this study have many implications for both radiographic science educators and for radiographic science students. Educators can use these findings to improve the implementation and use of virtual simulation in radiographic science education. Students can use these findings to improve their self-efficacy and positioning skills, thus increasing their clinical preparedness. These findings are summarized in Table 12 and expounded in the following sections.

Table 13. Summary of Implications for Educators and Students

Educators should:	**Students should:**

• Mitigate technical barriers
  o Computing requirements (e.g. operating system, computer specifications)
  o Tutorial and/or instructions of operation
• Provide some structure to the "sandbox"
  o Balance schema with autonomy
• Help students "buy in" to using the program to increase students' use
  o Share research results with students
  o Implement consequences (either positive or negative) to help motivate students
• Leverage the benefits of real-time virtual image production and evaluation
• Use virtual simulation to practice basic skills so class and laboratory time can be used to develop advanced skills
• Evaluate the benefits of using virtual simulation alone versus with others
  o Social learning can help students
  o Group work may have negative side effects
• Consider administrator concerns of cost, educational program needs, and curricular implementation
	• Exploit the virtual benefits of a virtual simulation program
	  o Decreased need for equipment space and on-campus time
	• Engage in using a virtual simulation program
	  o Higher engagement leads to higher satisfaction and increased clinical readiness
	• Converge what they learn in class with how they use the simulation
	  o Consistent practice over time increases learning retention (i.e. distributed practice)

Implications for Educators

The findings for this study have implications for radiographic science educators. Virtual positioning simulation software can help increase student self-efficacy and positioning skills. Based on the data collected from participants of this study there are a number of implications which can help radiographic science educators better prepare students for the clinical setting.

Educators should help mitigate technical challenges of using a simulation program. Educators should explore the technical criteria required to operate virtual simulation programs on computers and other electronic devices, such as computing power and memory, and compatibility with various operating systems (e.g. Windows©, macOS©, etc.). Providing students with computer equipment, either borrowed from the institution for personal use or access to on-campus computer labs, may help mitigate some of these technical issues. Based on students' comments, educators should also provide students with adequate instruction on how to use the simulation program and not assume students have prior experience using computer-based games or simulations. Such instruction could include tutorial sessions (either in-person or recorded videos), written guides, or peer-to-peer mentorship for learning how to use the simulation program.

This research study was designed to supplement students' practice time for on-campus laboratory practice; therefore there was no instruction given to students as to the purpose or structure of using the virtual simulation program. It was assumed students would use the simulation to practice for laboratory testing and to help practice exams with which they were not comfortable or proficient. The purpose to giving students the simulation software was to give them an open, "sandbox" style space to practice radiographic positioning. Though all the students stated they associated their use of the virtual simulation to didactic instruction, it was assumed this association would be enough for students to find using the simulation a valuable experience on its own. Student feedback suggests they would prefer to have more structure as to how they would use the simulation program. Adult learners desire a balance of structure and freedom; they have been groomed through educational experience to expect traditional pedagogical techniques (Cross, 1982; Hulse, 19991), but they also desire self-pacing and autonomy (Kong et al., 2015; Olxaewski & Wolbrink, 2017). Educators should give students some form of framework, schema, or objectives to using the simulation program so as to give them purpose and direction without being too prescriptive.

Based on feedback in this study, educators must consider how to get students to "buy in" to using the simulation program. The feedback from students showed the more time they spent using the simulation, the more it positively impacted their self-efficacy and positioning skills. If students do not invest the time necessary to become familiar with using the simulation, they may never feel using the simulation is a valuable exercise. Sharing the results of this and similar research studies can help students realize the positive implications of using a virtual simulation program. This research study was based on students' voluntary participation. There was no grade or consequence (positive or negative) tied to using or not using the simulation program. Because of this, some students did not use the simulation program because they did not see the benefit of using the program outweighed the cost of time and effort. Educators should take into account students' motivation in using a simulation program and tie using the simulation to tangible consequences. Educators could use positive consequences such as extra credit on assessments or praise from the educator for using the simulation, or they could use negative consequences such as grade deductions or increased workload for not using the simulation.

Real-time radiographic image evaluation is difficult to accomplish in an educational setting. Laboratory time is used to practice radiographic positioning on other students, but these positions cannot then be exposed to produce a radiographic image because of ethical concerns of unnecessary exposure to ionizing radiation. In the clinical setting, students can make exposures of real patients and then evaluate their radiographic images, but they are not allow opportunities to practice or change the position and see the resultant radiograph. Virtual simulations can help educators and students with image evaluation practice. Students can position and manipulate the virtual avatar to any position and then virtually expose the image to produce a radiograph. Students and educators can then critically evaluate the images in a safe and risk free environment which will help improve students' image evaluation skills in a real-life setting.

Because the virtual simulation program lacked variation in the virtual patient, educators should focus didactic instruction and laboratory practice on elements that cannot be practiced through the virtual simulation. Some of these elements include patient interactions and communication, body habitus, and atypical clinical presentation (trauma, bariatric, geriatric, pediatric, altered mental status, decreased mobility, etc.). Enhancing technical skills through virtual simulation can allow students to concentrate on other skills that can only be obtained in the clinical setting (Bridge et al., 2016; Shanahan, 2016b). Educators can instruct students to use the virtual simulation for learning standard or textbook case scenarios (i.e. learn the basics), so they can use class and laboratory time to learn more advanced or complicated material and skills.

When using a virtual simulation, educators must evaluate the benefits of having students use the simulation alone or with other students. All students interviewed in this study stated they used the simulation by themselves, with the exception of seeking technical support on how to use the simulation. Students also reported they did not want to use the simulation with other students and that being required to do so may exposure students to the negative aspects of group work, such as disengagement and non-participation. Still, according to social learning theories, radiographic science students do learn from others in collaborative efforts and from technologists in the clinical setting (Upadhyay & Williamson, 2010). Therefore it may be necessary for educators to incorporate some elements of social learning into simulation use. Educators may also need to identify students who would prefer to use the simulation alone and students who would prefer to use the simulation with others as student preference can impact learning (Shanahan, 2016b).

Educators who are also administrators must consider additional aspects of implementing virtual simulation in a radiographic science educational curriculum. The monetary cost for purchasing simulation software is substantial, and the cost for each type and brand of simulation program varies greatly. Besides initial purchase costs, update and subscription costs must also be considered. Each simulation program has differences as to how the program operates, computing requirements, and functions of the simulation. Administrators should engage faculty to identify the needs of the radiography program and how each different simulation program can help meet programmatic needs and recognize where the simulation programs do not meet the needs of the educational program.

Implications for Students

The findings for this study have implications for radiographic science students. Students can see how the results of this study explore the effect using a virtual positioning simulation software can have on student self-efficacy and positioning skills.

Besides the aforementioned implications for educators, there are implications for students which can help them better prepare for the clinical setting.

Many of the students commented on the ability to practice radiographic positions virtually as having a positive impact on their self-efficacy and positioning skills. Practicing with the virtual software led students to feed better prepared to enter the clinical setting. While traditional practice and repetition is available through on-campus laboratory sessions, these experiences are limited in space and available time. Virtual simulation helps to give students more time to practice and eliminates the need for physical radiographic equipment.

Students may be reluctant to use virtual simulations because they are skeptical of virtual simulation's benefit or are unfamiliar with using simulation programs. Sharing the results of this study can help students "buy in" to using virtual simulation programs. If student embrace using a simulation program as a supplement to traditional radiographic positioning practice, they can help to overcome their own bias against using a simulation. Also, students who are engaged or have a desire to use a simulation program are more likely to overcome technical and user familiarity challenges associated with learning how to use a new computer program.

Students should converge what they learn in traditional class and laboratory practice time with how they use the simulation. All the students in this study reported they used the simulation in conjunction with what they were learning in the didactic course. The more students increase their belief that they can accomplish required tasks (i.e. self-efficacy) and have the physical ability to do so (positioning skills), the greater prepared they will be to perform radiographic examinations in the clinical setting (Ortiz, 2015). Associating the didactic course with simulation use and practicing over time, the basis of distributed practice, increases learning retention and can help students feel better prepared to enter the clinical setting (Kapp, 2012; Tshibwabaw et al., 2017).

Conclusions

Students who enter the clinical setting unprepared can produce sub-quality radiographic images, expose patients to unnecessarily high amounts of radiation, and decrease patient care. RS programs must establish a way to evaluate students' competence as part of preparing students to enter a clinical setting. The purpose of this study was to investigate students' perceptions of their own self-efficacy and clinical skills (i.e. clinical preparedness) after using a virtual radiography simulation. The results of this mixed methods explanatory sequential research study explored how using a virtual radiography simulation program affected students' self-efficacy and positioning skills. Activity Theory provided a framework to organize the survey instrument and interview questions and to analysis the data collected.

The results of this study show that using a virtual simulation positioning software can be effective in helping to increase student self-efficacy and positioning skills. Students highly associated their use the simulation program to what they learned in traditional class and laboratory sessions. Virtual simulation removes some of the barriers of traditional positioning practice such as limited time, space, and equipment. However, other barriers such as technical issues and a lack of familiarity with the virtual program decreased some students' ability to effectively use the simulation program.

The conclusions drawn from this research can help provide educators a base of information on how students perceive their own clinical readiness after using a virtual simulation program and can guide further research studies of virtual simulation in health care education.

Future Research

The results of this mixed methods study indicated the need to further study simulation learning and the process of increasing students' clinical readiness (i.e. self-efficacy and positioning skills). Given the increase in distance learning and online education in recent years, especially during the COVID-19 pandemic, it is anticipated that the educational strategy of simulation learning will continue to become an important part of radiographic science education. Future research should focus on the elements identified as limitations of this study.

In addition, future quantitative research studies should use enough participants to run robust statistical analysis, allowing researchers to develop conclusions based on more than just averages and mean scores. More study participants would allow for a greater statistical analysis of each tenet of AT as well as each individual criterion of a survey.

Another avenue for research would be to explore the proper amount of time students need to use a virtual simulation program to gain the maximum benefit. The current research project asked students to use the simulation program for at least one hour per week. Most students in this study used the simulation for less than one hour per week, and since the number of participants was so small, no statistical analysis could be run as to evaluate a convergence between use time and perceived impact. No research has been performed as to determine the proper amount of time students should use a simulation program. Future research should investigate the proper amount of time needed to see a benefit of using virtual simulation without being too much as to induce negative effects on the student such as demotivation or burnout.

The effectiveness of using the simulation alone or with others should also be explored in future research. In this study as with similar studies, participants were asked about their preference in using the simulation alone or with others. There has been no analysis as to the effectiveness of using a simulation program alone versus using a simulation program with others. Future research should compare the effectiveness of using a simulation alone to the effectiveness of using a simulation with others or in a group setting. Such findings would have implications for how educators incorporate a simulation into a curriculum

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APPENDIX A

Survey Instrument

Using Radiographic Virtual Positioning Simulation in an Undergraduate Radiography Course

Christopher Wertz, a graduate student at Boise State University, is conducting a research study to evaluate the effect of implementing virtual radiographic positioning software in Radiographic Science Program curriculum. You are being asked to complete this survey because you are enrolled in a Radiographic Science class this semester.

Participation is voluntary. You do not have to be in this study if you do not want to. If you volunteer to be in this study, you may withdraw from it at any time without consequences of any kind or loss of benefits to which you are otherwise entitled. Your participation or declination of participation will have no positive or negative affect on any of your grades or standing in the Radiographic Science Program. All participation with the virtual radiography positioning software is voluntary; no elements of participation are required as part of course requirements. The survey will take approximately 15 minutes or less to complete. You must be at least 18 years old to take this survey.

You will not be paid or compensated for your participation in this research study. There will be no direct benefit to you from participating in this study. However, the information that you provide may help radiography educators better grasp student reactions to using a virtual radiographic positioning software program and the effects virtual simulation has on clinical performance. Also, because you will be answering questions regarding your own learning, you may receive additional insights into your own attitudes and behaviors as part of the learning process.

The survey will include a section requesting demographic information. Due to the make-up of Idaho's population, the combined answers to these questions may make an individual person identifiable. We will make every effort to maintain confidentiality. We ask that you try to answer all questions; however, if there are any items that make you uncomfortable or that you would prefer to skip, please leave the answer blank. Your responses are anonymous.

If you have any questions or concerns feel free to contact Christopher or his faculty advisor:

Christopher Wertz, graduate student
Educational Technology
(208) 282-2871
chriswertz@u.boisestate.edu

Dr. Brett Shelton, Professor
Educational Technology
(208) 426-3391
brettshelton@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.

If you would prefer not to participate, please do not fill out a survey. If you consent to participate, please complete the survey.

- ○ I consent
- ○ I do not consent

What is your age?

	18 22 26 31 35 39 43 47 52 56 60
Age	

What is your gender?

- ○ Male
- ○ Female
- ○ Other
- ○ Prefer not to say

What is your ethnicity?

- White
- Hispanic or Latino
- Black or African American
- Native American
- Asian/Pacific Islander
- Other
- Prefer not to say

Please select how much you agree or disagree with the following statements:

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I liked using MedspaceXR	○	○	○	○	○
MedspaceXR is easy to use	○	○	○	○	○
Technical problems made using MedspaceXR difficult	○	○	○	○	○

On average, how much time did you spend each week using MedscapeXR

- 0-30 minutes
- 30-60 minutes
- 1-2 hours
- 2-3 hours
- 3-4 hours
- more than 4 hours

Please select how much you agree or disagree with the following statements:

Using MedspaceXR...

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Enhanced my routine procedure for setting up radiographic examinations	○	○	○	○	○
Allowed me to quickly see images and understand if changes needed to be made	○	○	○	○	○
Enhanced my image evaluation skills	○	○	○	○	○
Helped me become more fluent or systematic in a radiographic examination e.g. not repeating steps	○	○	○	○	○
Helped me learn as I was able to repeat activities until I was satisfied with the results	○	○	○	○	○
Had a positive effect on my ability to set up a radiographic examination	○	○	○	○	○
Had a positive effect on my ability to evaluate radiographic images	○	○	○	○	○

Please select how much you agree or disagree with the following statements:

Using MedspaceXR...

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Had a positive effect on my confidence level in setting up radiographic examinations	○	○	○	○	○
Had a positive effect on my confidence level in evaluating radiographic images	○	○	○	○	○
Had a positive effect on my ability to self-evaluate when I set up radiographic examinations	○	○	○	○	○
Had a positive effect on my ability to self-evaluate when I evaluate radiographic images	○	○	○	○	○
Encouraged me to think more about radiographic procedures	○	○	○	○	○
Encouraged me to think more about evaluating radiographic images	○	○	○	○	○
Encouraged me to solve problems	○	○	○	○	○

I learn best with MedspaceXR when it is:

○ an individual activity (I used MedspaceXR on my own)

○ a shared activity (I used MedspaceXR with 1 or 2 students)

○ both/either an individual or shared learning activity

Please select how much you agree or disagree with the following statements:

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
MedspaceXR was designed to help guide me through positioning activities	○	○	○	○	○
The MedspaceXR reference guide was a valuable tool in helping me use the VR program	○	○	○	○	○
I relied on other students to help me learn using MedspaceXR	○	○	○	○	○

Please provide any additional feedback about your experience using MedspaceXR including how it affected your confidence in radiographic positioning, how it affected your clinical skills, and/or your interactions with using the MedspaceXR program.

____

APPENDIX B

Institutional Review Board Exemption

BOISE STATE UNIVERSITY
RESEARCH AND ECONOMIC DEVELOPMENT

Date: August 26, 2019

To: Christopher Wertz cc: Brett Shelton

From: Office of Research Compliance (ORC)

Subject: SB-IRB Notification of Exemption - 101-SB19-166
Using Virtual Radiographic Positioning Simulation in an Undergraduate Radiography Course

The Boise State University ORC has reviewed your protocol application and has determined that your research is exempt from further IRB review and supervision under 45 CFR 46.101(b).

Protocol Number: 101-SB19-166	Received: 8/12/2019	Review: Exempt
Expires: 8/25/2022	Approved: 8/26/2019	Category: 2

This exemption covers any research and data collected under your protocol as of the date of approval indicated above, unless terminated in writing by you, the Principal Investigator, or the Boise State University IRB. All amendments or changes (including personnel changes) to your approved protocol **must** be brought to the attention of the Office of Research Compliance for review and approval before they occur, as these modifications may change your exempt status. Complete and submit a Modification Form indicating any changes to your project.

Exempt protocols are set to expire after three years. Annual renewals are not required for exempt protocols. If the research project will continue beyond three years, a new application must be submitted for review. If the research project is completed before the expiration date, please notify our office by submitting a Final Report.

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.

Office of Research Compliance

1910 University Drive Boise, Idaho 83725-1139
Phone (208) 426-5401 orc@boisestate.edu
This letter is an electronic communication from Boise State University

APPENDIX C

Informed Consent for Interviews

INFORMED CONSENT FORM
Study Title: **Using Virtual Radiographic Positioning Simulation in an Undergraduate Radiography Course**
Principal Investigator: **Christopher Wertz**
Co-Principal Investigator: **Dr. Brett Shelton**

You are invited to participate in a research study. This consent form will provide you the information you will need to understand why this study is being done and why you are being invited to participate. It will also describe what will be expected of you as a participant, as well as any known risks, inconveniences or discomforts that you may have while participating. We encourage you to ask questions at any time. If you decide to participate, you will be asked to sign this form and it will be a record of your agreement to participate. You will be given a copy of this form to keep.

PURPOSE AND BACKGROUND

The purpose of this study is to investigate students' perceptions of their own self-efficacy and clinical skills after using a virtual radiography simulation in an undergraduate course. You are being asked to participate because you are a first year radiography student at Idaho State University who used the MedspaceVR simulation program and completed the survey about your perceptions

PROCEDURES

If you agree to be in this study, you will participate in the following:

- One 60-minute interview about your study habits.

We will set up a time for you to meet the investigator via Zoom due to the current COVID 19 restrictions. You will complete the interview for a total of 60 minutes of participation. <u>The interview will be audio and video recorded and the investigators will take written notes as well.</u>

____ *Initial to indicate your permission to be audio recorded during the interview.*

RISKS

Some of the interview questions might make you feel uncomfortable or upset. You are always free to decline any question, take a break, or to stop your participation at any time. Should you feel discomfort after participating, please contact your health care provider or call the Idaho Care Line, 2-1-1 (a free statewide community information and referral service).

BENEFITS

There will be no direct benefit to you from participating in this study. However, the information that you provide may help develop improved study habits for future college students.

EXTENT OF CONFIDENTIALITY

Reasonable efforts will be made to keep the personal information in our research records private and confidential. Any identifiable information obtained in connection with this study will remain confidential and will be disclosed only with your permission or as required by law. The members of the research team, and the Boise State University Office of Research Compliance (ORC) may access the data. The ORC monitors research studies to protect the rights and welfare of research participants.

The recordings from the interview will be transcribed without any information that would identify you. The recordings will then be deleted. Your name will not be used in any written reports or publications which result from this research. Data will be kept for at least 3 years (per federal regulations) after the study is complete and then destroyed.

PAYMENT/COMPENSATION

You will not be paid or compensated for your participation in this research study.

PARTICIPATION IS VOLUNTARY

Your decision to participate in this research study is entirely voluntary. You may withdraw from this research study at any time without penalty of any kind or loss of benefits to which you are otherwise entitled.

QUESTIONS

If you have any questions or concerns about your participation in this study, you may contact the Principal Investigator, Christopher Wertz at 208-282-2871 or chriswertz@u.boisestate.edu or Co-Principal Investigator, Dr. Brett Shelton at 208-426-3391 or brettshelton@boisestate.edu.

This study has been reviewed and approved by the Boise State University IRB (IRB). If you have questions about your rights as a research participant, you may contact the IRB, which is concerned with the protection of volunteers in research projects. You may reach the board through the Office of Research Compliance by calling (208) 426-5401 or emailing humansubjects@boisestate.edu.

DOCUMENTATION OF CONSENT

I have read this form and the descriptions of this research study. I have been informed of the risks and benefits involved and all of my questions have been answered to my satisfaction. Furthermore, I have been assured that any future questions I may have will also be answered by a member of the research team. I understand I can withdraw at any time. I voluntarily agree to take part in this research study.

____________________________ ____________________________________

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

____ _______________

Signature of Person Obtaining Consent | Date